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DETERMINATION OF PRESS BRAKE BENDING PARAMETERS FOR HARDOX 400 STEEL

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Abstract: In the present study, a specific hydraulic press brake based test setup (HPBTS) was designed and manufactured which was used to determine the bending forces and the punch displacements of Hardox 400 steel depending on the plate thickness, plate length and mechanical properties. The setup was equipped with an image processing system to detect the change of the bending angle during forming. Prior to bending tests, tensile tests were carried out and the identified mechanical properties were compared with the ones reported by the manufacturers. The effect of the difference between the mechanical properties on the bending parameters was investigated. Air bending technique was used for bending tests. Experiments were carried out with varying plate thicknesses, plate lengths, bending angles, forming speeds and channel openings using flat materials supplied from two different manufacturers. The effect of these parameters on bending force, displacement and springback angle was revealed. It was shown that the mechanical properties of Hardox 400 steel vary according to the manufacturer. The difference between the measured mechanical properties and the ones obtained from the manufacturers had a direct influence on the bending properties.

Keywords: Hardox 400 steel, Hydraulic press brake based test setup, Air bending

Hardox 400 Çeliği için Hidrolik Abkant Preste Bükme Parametrelerinin Belirlenmesi

Öz: Bu çalışmada, Hardox 400 çeliğinin levha kalınlığı, levha uzunluğu ve mekanik özelliklerine bağlı olarak bükme kuvvetlerini ve zımba yer değiştirmelerini belirlemek için kullanılan özel bir hidrolik abkant pres tabanlı test düzeneği (HPBTS) tasarlanmış ve üretilmiştir. Kurulum, şekillendirme sırasında bükme açısının değişimini algılamak için bir görüntü işleme sistemi ile donatılmıştır. Bükme testleri öncesinde çekme testleri yapılmış ve tespit edilen mekanik özellikler imalatçıların bildirdiği özelliklerle karşılaştırılmıştır. Mekanik özellikler arasındaki farkın bükme parametreleri üzerindeki etkisi araştırılmıştır. Bükme testleri için havada büküm tekniği kullanılmıştır. Deneyler, iki farklı üreticiden temin edilen yassı malzemeler kullanılarak farklı levha kalınlıkları, levha uzunlukları, bükme açıları, bükme hızları ve kanal açıklıkları ile gerçekleştirilmiştir. Bu parametrelerin bükme kuvveti, yer değiştirme ve geri yaylanma açısına etkileri ortaya çıkarılmıştır. Hardox 400 çeliğinin mekanik özelliklerinin üreticiye göre farklılık gösterdiği belirlenmiştir. Ölçülen mekanik özellikler ile imalatçılardan elde edilenler arasındaki farkların, bükme özellikleri üzerinde doğrudan bir etkiye sahip olduğu anlaşılmıştır.

Anahtar Kelimeler: Hardox 400 çeliği, Hidrolik abkant pres tabanlı test düzeneği, Havada büküm

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1. INTRODUCTION

In sheet metal forming industry flat materials obtained from different manufacturers are usually utilized. The chemical and mechanical properties of the materials may differ from one manufacturer to another even if they are produced according to the same standards. It is well known that mechanical properties like yield stress, ultimate stresses, elongation and so on directly affect the bending properties and processes. In manufacturing machine and die components, the mechanical property values or ranges given by the material suppliers are accepted as is. However, the measured mechanical properties and the ones supplied by the manufacturers may vary about 10-15%. This leads to designs with safety factors overestimated by 5-10% or even in some cases as high as 20% (Aydemir, 2017). In the contrary case, when insufficient safety factors are used, required bending forces may not be achieved and the specimens may be discarded.

One of the biggest problems encountered in sheet metal bending processes is springback. Especially in the air bending technique without pressing, higher springback values occur due to many different factors. Springback varies depending on the following reasons.

- Sheet material thickness
- Chemical structure of the material
- Material mechanical properties
- Forming time
- Waiting time at bending moment
- Tool dimensions
- Bending force

In the literature, a variety of studies regarding different aspects of air-bending technique are present and the relevant ones are summarized here. If the bend radius / material thickness (R/S) ratio is large, the amount of springback is correspondingly larger. It is known that springback varies in direct proportion with the bending radius, and as the bending radius increases, the amount of springback increases. (Wang et al.2008)

Canteli et al. (2008) designed and manufactured an air bending test setup to perform tests with AISI 304 stainless steel. They constituted a thermomechanical model as well as a theoretical one from which they compared the results with the experiments. The model predictions of bending force and springback angle were found to be within 5% and 1.5% accuracy, respectively. Further, the effects of varying sheet thicknesses, upper die radiuses and die openings on the upper die displacement-bending force curve were investigated by the constituted model. The bending length and the maximum bending force in the experiments were 3050 mm and 900 kN, respectively. Bending force was measured by both a load cell and a pressure sensor.

In another work, a theoretical model for bending was developed by using Timoshenko's beam theory (Coelho et al., 2005). According to this model, bending angle was found to be dependent on the upper die displacement substantially.

Various other subjects were inquired in this respect, such as optimum die geometry determination and suitable methods to provide effective working of the operator (Duflou et al., 2005). Duflou et al. (2005) made suggestions for the fundamental problems of bending process e.g. bend sequencing, collision detection, tolerance verification and tool selection. Reducing the required bending force for the thick sheets via local heating has been another research topic. In an experimental work performed using a 25 mm thick sheet, the bending force could be decreased as much as 55% when local heating (reaching 630°C in 5 minutes) was applied (Duflou and Aerens, 2006).

Another study emphasized that in bending processes with small bending radius, the quality control of the first product is essential when excessive number of small products with high quality is aimed at (Elkins and Sturges, 1999). It was stated that plate thickness and hardness should be measured offline, on the other hand, this measurement should be done online for the upper platform position and loading angle.

Gupta et al. (1998) concentrated on automatic bending process while Mentink et al. (2003) determined the properties of an arbitrarily chosen material subjected to air bending. Ona and Watari (1998) eliminated the longitudinal skewness in a product formed in a hydraulic press brake based setup.

Yet another issue is the high energy requirement for the production of the work tools of the hydraulic press brake based setup with a high precision. Santos et al. (2011) revealed the redundant energy consumption and emphasized on the need for the efficient use of energy in hydraulic press brake based setups.

Finite element studies to investigate various parameters have been a common method, too. Singh et al. (2004) enquired the effects of work tool geometry on the final product numerically. Their results indicated that even small changes in the tool penetration caused major variations regarding the bending performance such as bending angle. Similar numeric studies were performed by Thipprakmas (2010) and Chan et al. (2004).

Springback angle is one of the most fundamental problems in bending and prediction of the springback angle is commonly studied numerically or experimentally by Saric et al., 2016, Marcondes et al., 2016 and Adnan et al., 2017. Considering the outcomes of the numerical studies, bending angle was remarked as the parameter which affects the springback angle mostly.

In an experimental work, Wang et al. (2008) proposed a method to predict the springback angle and control the bending angle more effectively. Asnafi (2000) performed air bending tests with different stainless steels of different classes and thicknesses using a V-die and proposed an analytical method to predict the springback angle. Fei and Hodgson (2006) studied the springback of colled rolled TRIP steels subjected to air bending experimentally, using sheet thicknesses of 1.2, 1.45 and 1.6 mm. Ultra-high strength steels and their formability was also emphasized concerning the vehicle weight reduction by some researchers (Mori et al., 2007).

Hardox 400 steel is a material which possesses high forming and welding ability as well as wear resistance with low carbon equivalent. It is especially preferred in parts where wear is critical such as construction machines, scrapers, loaders, trucks, presses. In addition to these properties, Hardox 400 material is light and bends easily, resulting in long-lasting and easy-to-use products. So far, various studies dealing with different aspects of the air bending method was summarised. It was seen that bending properties of Hardox 400 steel has not been discussed. For this reason, Hardox400 material was chosen as the material in interest. This study presents the air bending test results of Hardox 400 steel, i.e., bending force, upper die displacement and springback angle with respect to forming speed, bending angle and plate dimensions. Materials supplied from two different manufacturers were used to display the difference between the mechanical properties reported by the manufacturers and the measured ones. The effect of this difference on the bending properties was investigated.

2. MATERIAL AND METHOD

2.1. Material

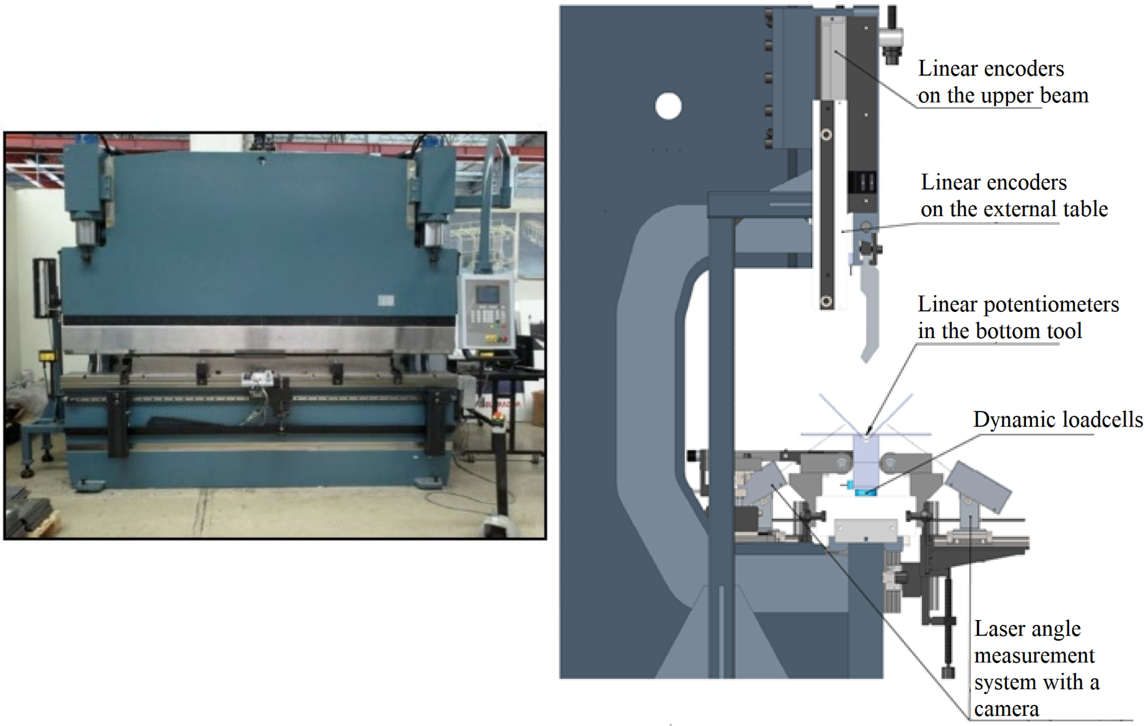
Within the scope of this study, flat specimens (plates) made from Hardox 400 steel were used. The plates were produced at two different thicknesses (4 and 6 mm) to investigate the effect of thickness on bending properties. To analyse the effect due to the variation in the chemical composition and the mechanical properties, Hardox 400 steel was supplied from two different manufacturers. The chemical composition and mechanical properties of the materials obtained from the manufacturers are listed in Table 1.

Table 1. Chemical composition and mechanical properties of the Hardox 400 steel obtained from the manufacturers

Manifacturer	%C	%Si	%Mn	%P	%S	%Cr	%Ni	%Mo	%B	R_e [MPa]	R_m [MPa]	%A5	Micro-hardness HB
K	0.11	0.28	0.99	0.008	0.003	0.20	0.04	0.019	0.002	1000	1250	10	400
E	0.13	0.23	1.61	0.011	0.003	0.24	0.03	0.005	0.001	1000	1250	10	400

2.2 Hydraulic Press Brake Based Test Setup (HPBTS)

A specific test set up was designed and manufactured to carry out the air bending tests. The angle measurement device, linear potentiometer, linear encoders and dynamic load cells were installed as shown in Figure 1.

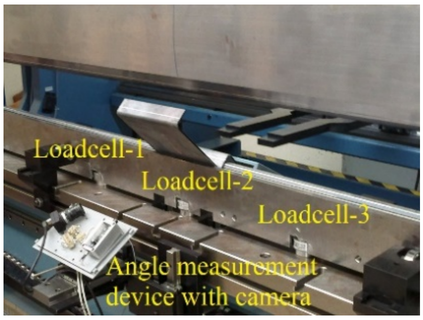


a. *b.*

Figure 1:
a. *The manufactured hydraulic press brake based test setup* ***b.*** *Schematic layout of the test setup with the auxiliary equipment and measurement devices*

Due to the reason that bending tests speeds were between 5 mm/s and 15 mm/s, dynamic load cells were utilized. Three dynamic load cells with a capacity of 1000 kN were used to measure force values in bending (Figure 2). The load cells were placed under the bottom tool of

Hydraulic Press Brake Setup. Bending forces were calculated for parameters such as different thickness, different length, different bending angle, different bending rate and different channel openings using the data obtained from the load cells.



a b

Figure 2:
Dynamic load cells placed under the bottom tool for force measurements
a) Dynamic load cell, b) Placement of load cells in HAPDD

The dynamic load cells were calibrated on Instron brand universal test device before bending tests (Figure 3).

Figure 3:
Dynamic load cell calibration

The mechanical properties of the calibrated rod type special load cell is listed below:
- Minimum load : 0% of working load
- Maximum load : Up to 120% of working load
- Maximum allowable overload : 150% of working load
- Fracture loading: When it exceeds 300% of the working load
- Maximum lateral loading : 10% of the working load
- Maximum dynamic loading : 40% of working load

The electrical values of the load cell are given by the manufacturer as follows.
- Nominal sensitivity: 1mV/Volt
- Supply voltage: N.10V 2 – 15 Volt
- Nominal operating temperature: -10/+40 °C

- Cell material: High strength stainless steel

2.3 Tension Tests

Prior to bending tests, tension tests of Hardox 400 steel were carried out to identify the differences between the measured mechanical properties and the ones supplied by the manufacturers. Plates which were cut in and perpendicular to the rolling direction were prepared according to the ASTM E8 (ASTM E8/E8M, 2016). Wet machining was applied after cold cutting of the plates to the dimension of 53 mm x 310 mm.

Tension tests were performed at a speed of 10 mm/min by a universal tension-compression testing machine which has a capacity of 250 kN. Stress-strain plots for the materials were obtained and used for determining yield stress, tension stress and elongation strains. Subsequently, these values were compared with the ones reported by the manufacturers. Tension test specimens before and after the tests are seen in Figure 4.

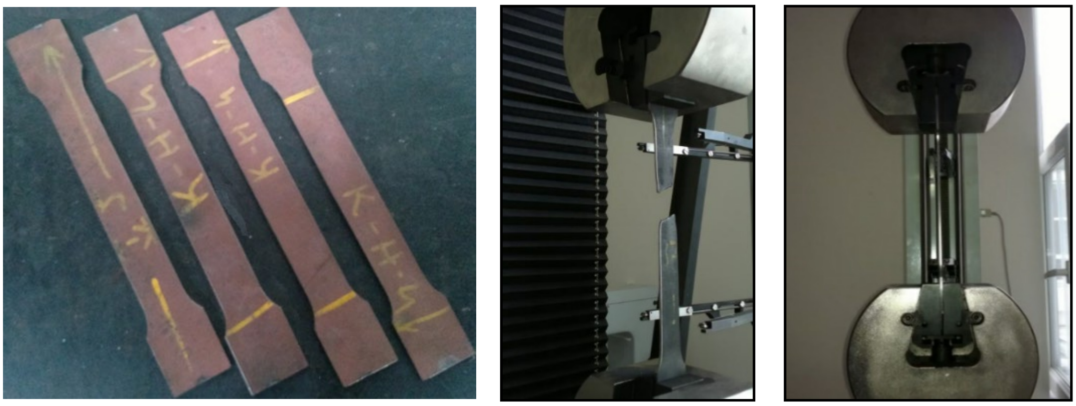


Figure 4:
Tension Tests

2.4 Air Bending Tests

Schematic of the air bending test method is demonstrated in Figure 5. The thickness and length values of the plates were determined considering the bending angle, displacement and force measurements. Since the plate width was not a parameter in consideration, it was kept constant as 300 mm for all. In addition to thickness, plate length was selected as a parameter of whose effect on the bending properties would be examined. Thus, the plates were produced with two different lengths of 600 and 1000 mm. So, combinations of the overall dimensions for the total of 48 plates consisted of 4x300x600, 4x300x1000, 6x300x600 and 6x300x1000 mm.

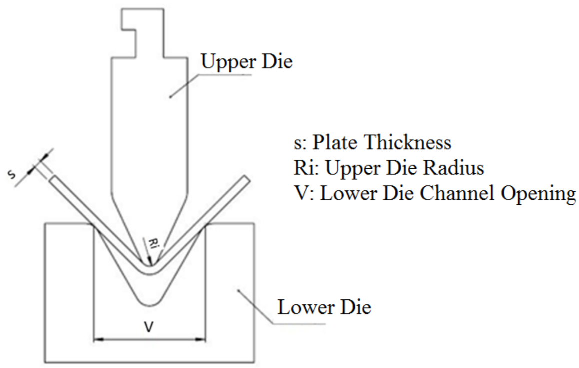


Figure 5:
Schematic of the airbending test method

At first, for each plate thickness, the bending tests had been aimed to be performed at 3 different bending angles and speeds for each plate dimension. In doing so, the total number of tests calculated was found to be significantly high. Thus, Taguchi method was used to decrease the number of tests. The number of levels for bending angle and speed were reduced to 2. Since two different thicknesses were used, Taguchi L8 method was applied. The test plan according to Taguchi design is given in Table 2.

Table 2. Bending test plan

Plate Thickness *[mm]*	Dimensions *[mmxmmxmm]*	Rolling Direction	Bending Angle *[°]*	Manufacturer	Forming Speed *[mm/s]*	Number of Experiments	Channel Opening *[mm]*	Plate Number		
								Plate 1	Plate 2	Plate 3
4	4x300x600	Perpendicular	90	K	5	3	60	1	2	3
	4x300x600		90	K	15	3		4	5	6
	4x300x1000		120	K	5	3		7	8	9
	4x300x1000		120	K	15	3		10	11	12
	4x300x600		90	E	5	3		13	14	15
	4x300x600		90	E	15	3		16	17	18
	4x300x1000		120	E	5	3		19	20	21
	4x300x1000		120	E	15	3		22	23	24
6	6x300x600		120	K	5	3	120	25	26	27
	6x300x600		120	K	15	3		28	29	30
	6x300x1000		90	K	5	3		31	32	33
	6x300x1000		90	K	15	3		34	35	36
	6x300x600		120	E	5	3		37	38	39
	6x300x600		120	E	15	3		40	41	42
	6x300x1000		90	E	5	3		43	44	45
	6x300x1000		90	E	15	3		46	47	48
						48				

Bending test speeds of 5 mm/s and 15 mm/s were applied to investigate the effect of this parameter on bending force. Due to the fact that channel opening has a direct influence on the bending force, the plates with the same dimensions were bended in the same die set. The tests at the selected speeds were carried out at different bending angles: 90° and 120° in order to see the effect of this parameter. Springback angles were measured by the angle measurement device which was equipped with a camera and placed at the front and back of the lower die. The parameters of plate length, plate thickness, bending angle, speed and lower die channel opening could vary depending on the rolling direction. So, it was ensured that all of the plates were extracted from the direction perpendicular to the rolling direction. For each plate dimension, tests were repeated 3 times. In Figure 6, image of a plate after air bending test is given.

Figure 6:
Image of a plate subjected to air bending

The vertical displacement of the upper die was measured by 2 linear encoders positioned at the machines upper surface. Another encoder was placed externally. The external encoder was required to validate the displacement values, since, due to the deflection at the upper die, measurements from the encoders placed at the upper surface may contain some error. Displacement calculations were done by 2 linear potentiometers which were in contact with the plate inside the die. Subsequently, these values were compared with the ones obtained from the encoders.

After completing the tests, bending force-displacement plots for varying parameters were constituted. Bending force values were measured by three dynamic load cells which were placed under the upper die.

As mentioned before, for the same plate thickness, always the same die set was utilized. Since plates were produced in two different thicknesses, two different die sets were used. For the plates with 4 mm thickness, die set had a 60 mm channel opening and a die tip with a R10 radius; whereas for the plates with 6 mm thickness, these values were 120 mm and R15, respectively.

Labview software was used to receive the signals from the sensors simultaneously. The data was collected at every 10 milliseconds and recorded to excel files. The data gathered in TDMS file were exported to excel file simultaneously by the Labview software. The data received from the potentiometer and encoders were automatically converted to mm, while the voltage signal received from the load cells were converted to force values by using calibration results. In each row, the values received from each sensor were recorded for every 10 milliseconds. Depending on the bending test duration, the excel sheets consisted of 1000-2000 rows.

3. RESULTS AND DISCUSSION

3.1 Tension Test Results

Mechanical properties obtained from the tension tests are presented together with the ones supplied from the manufacturers in Table 3.

Table 3. Mechanical properties of Hardox 400 steel reported by the manufacturers and determined by tension tests

Rolling Direction	Manufacturer	σ_{max} [MPa]			σ_{yield}[MPa]			%ε (elongation)		
		Tension Tests	Manufacturer values	Difference%	Tension Tests	Manufacturer values	Difference%	Tension Tests	Manufacturer values	Difference%
Perpendicular	K	1227	1250	1.87	1067	1000	6.28	5.87	10	70.36
	E	1322	1250	5.45	1201	1000	16.74	4.76	10	110.08
Parallel	K	1225	1250	2.04	1074	1000	6.89	7.00	10	42.86
	E	1308	1250	4.43	1174	1000	14.82	6.02	10	66.11

When the mechanical properties supplied from the manufacturers were compared with the ones obtained from the tension tests, it was revealed that these values showed some difference. This difference was further shown to have a direct influence on the bending force, the displacement of the upper die and the springback angle.

3.2Air Bending Test Results

Raw data were obtained from sensors placed on the experimental setup to measure bending force, upper die displacements and bending angles. Simultaneous force-displacement plots were plotted for each test sample in Figure 7 and 8. In these graphs, it is possible to see the changes in the bending force and the displacements of the upper mold according to time. Additionally, the displacement values can be read simultaneously with respect to the force values during bending. As given in the experiment plan, the experiments of Hardox 400 materials were carried out at 2 different bending speeds, bending angles and channel openings.

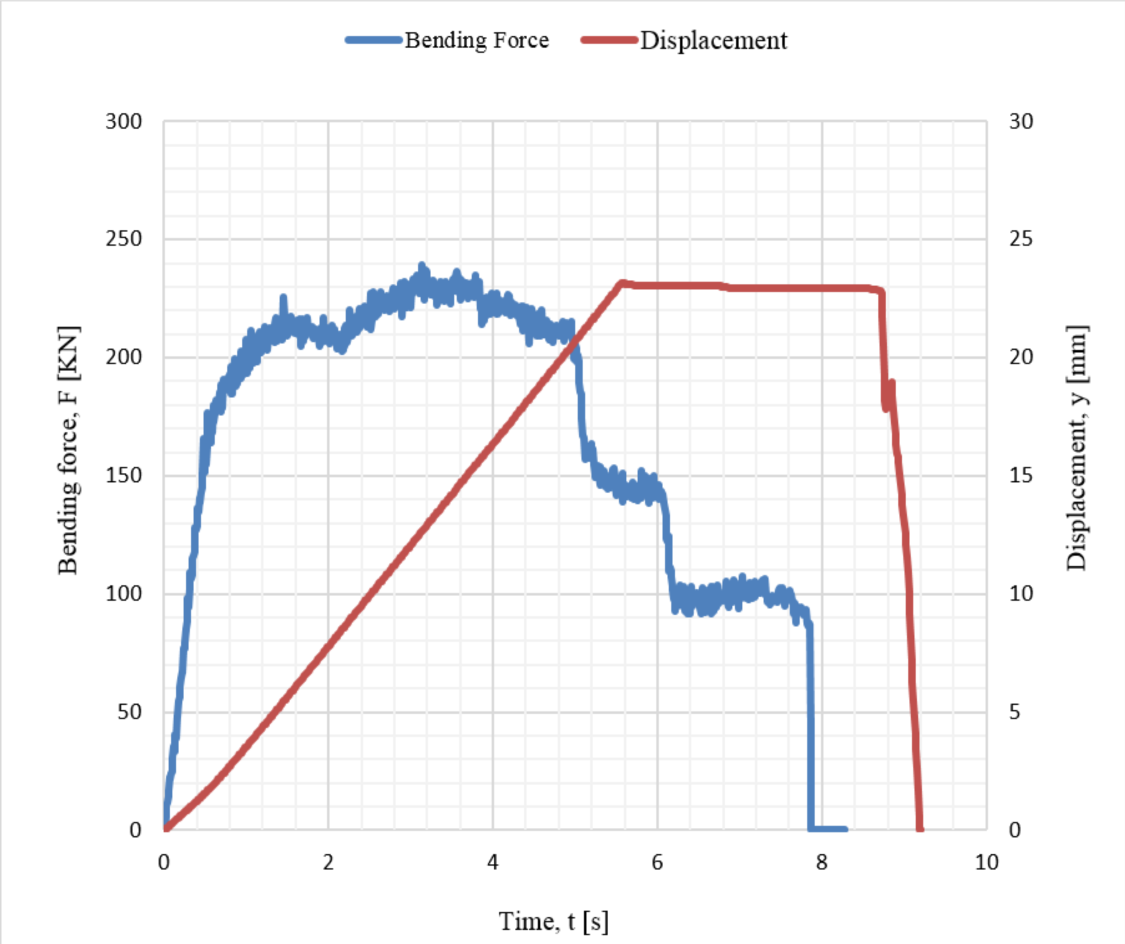


Figure 7:

Bending force-time and displacement-time curves of Hardox 400 plate from manufacturer K with dimensions of 4x300x600 mm, forming speed of 5 mm/s and channel opening of 60 mm subjected to 90° bending

In Figure 7, it is seen that bending force started to increase abruptly as soon as the upper die moved at a forming speed of 5 mm/s. After about 5 seconds, the bending process was completed at an upper die displacement of 24.206 mm. Afterwards, the upper die started moving back to reach its initial position at 8.35 seconds. The maximum bending force, 238.49 kN, was reached at 3.2 seconds while the upper die was performing the bending process.

The force-time and displacement-time plots of a plate with the same dimensions which was bended at a speed of 15 mm/s is given in Figure 6. In this test, the bending process was completed at 3.2 seconds and the upper die moved back to its initial position at 4 seconds. The maximum force was obtained as 258.26 kN at 1.1 seconds. The maximum force was approximately 20 kN higher than that of the test with 5 mm/s forming speed. This revealed that an increase in forming speed also increases the bending forces. The effect of forming speed on bending force was further analysed for other plates.

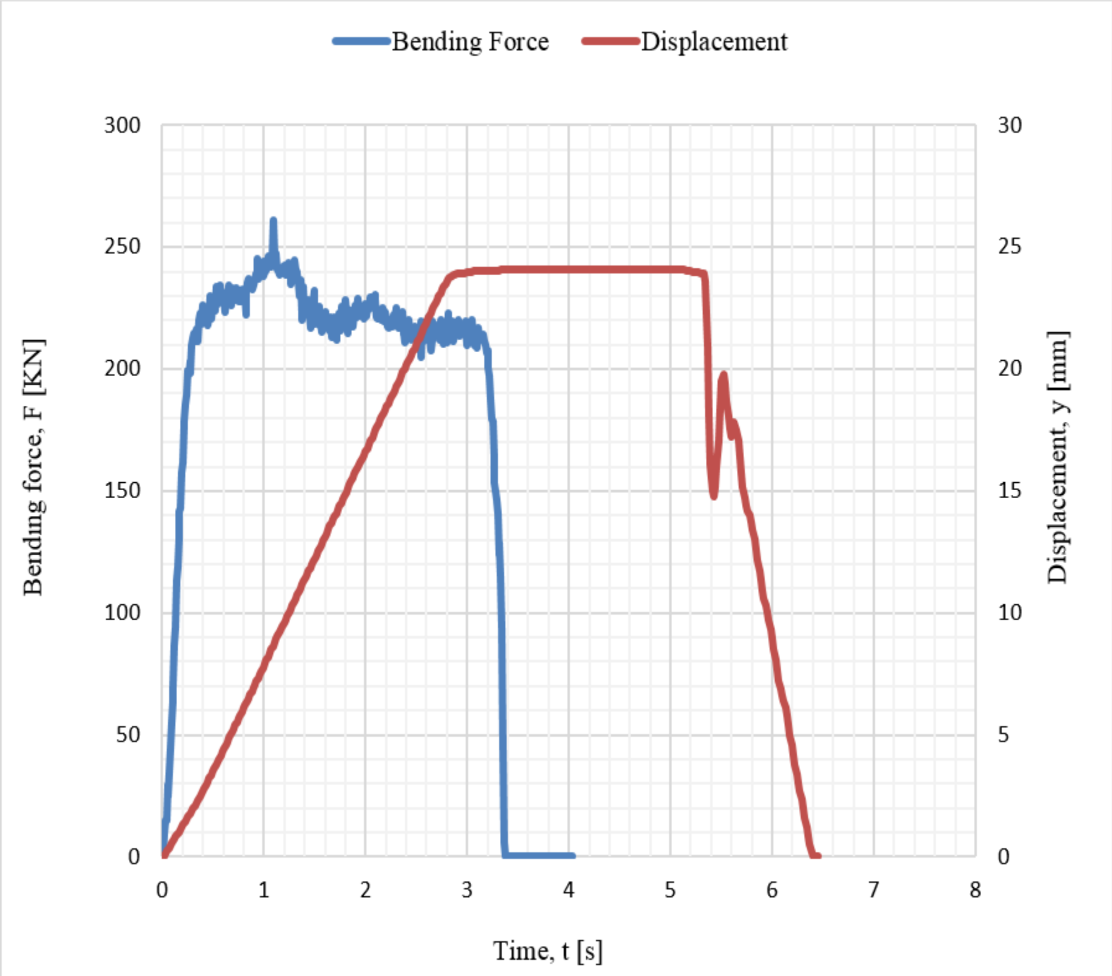


Figure 8:
Bending force-time and displacement-time curves of Hardox 400 plate from manufacturer K with dimensions of 4x300x600 mm, forming speed of 15 mm/s and channel opening of 60 mm subjected to 90° bending

It is known in the literature that the bending force increases in direct proportion to the bending length (Uckland et al. 2002). The bending force, which is affected by factors such as bending length, breaking stress of the material, material thickness and V channel width, is theoretically determined by the following formula (SSAB 2015). The bending forces of the test materials were calculated according to the tensile strength values given by the suppliers and recorded in Table 4 and compared with the values obtained on the test setup.

$$P = \frac{\mathrm{b\ x}\ t^2\ x\ \mathrm{Rm}}{(\mathrm{W} - \mathrm{Rd} - \mathrm{Rp})x\ 9800} \tag{1}$$

P = Bend force, tons
t = Plate thickness, mm
W = Die width, mm
b = Bend length, mm
Rm = Tensile strength, MPa
Rd = Die entry radius, mm
Rp = Punch radius, mm

Springback, which is fully elastic, increases with material's yield strength and the ratio between die width and plate thickness (W/t). To compensate for springback, the die should be shaped in such a way to allow over bending without the material. It is very difficult to accurately predict the springback of a material when bending, since it depends to a large extent on each unique tool setup. That is why trials are recommended. Manufacturer's estimated springback values are given Table 4 which were used for comparison with the results obtained from the experiments.

The maximum average bending forces, upper die displacements and springback angles for all tests are listed in Table 4. In this table, the effects of the parameters, namely plate thickness, dimensions, bending angle, forming speed, width of the channel opening on bending forces, upper die displacement and springback angle were exhibited. It was also revealed that these bending properties change according to which manufacturer the material is supplied from.

The bending angles of the plates were assured by measuring the angles manually via a digital angle measurement device 15 minutes after the bending processes.

Table 4. Bending force, upper die displacement and springback angle values of Hardox 400 for all tests

Plate thickness *[mm]*	Plate Dimensions *[mmxmmxmm]*	Bending Angle *[°]*	Manufacturer	Forming speed *[mm/s]*	Channel opening *[mm]*	Average bending force *[kN]*	Calculated bending force *[kN]* (1)	Average displacement of the upper die *[mm]*	Average springback angle *[°]*	Manufacturer estimated springback angle[°]
4	4x300x600	90	K	5	60	238.48±9.33	266.19	24.20 ± 0.19	12.11	9-13
	4x300x600	90	K	15		258.26±5.94	266.19	24.51 ± 0.51	11.75	9-13
	4x300x1000	120	K	5		404.80±4.07	443.65	15.82 ± 0.22	8.19	5-8
	4x300x1000	120	K	15		411.79±6.72	443.65	15.43 ± 0.26	7.54	5-8
	4x300x600	90	E	5		240.84±8.15	266.19	24.33 ± 0.27	14.58	9-13
	4x300x600	90	E	15		263.85±6.02	266.19	24.02 ± 0.17	14.32	9-13
	4x300x1000	120	E	5		407.29±7.66	443.65	15.04 ± 0.17	7.00	5-8
	4x300x1000	120	E	15		421.91±9.60	443.65	15.06 ± 0.37	8.41	5-8
6	6x300x600	120	K	5	120	310.24±8.09	278.29	31.21 ± 0.40	11.59	5-8

	6x300x600	120	K	15		316.72±4.81	278.29	30.97 ± 0.52	11.91	5-8
	6x300x1000	90	K	5		452.95±7.96	463.82	50.90 ± 0.55	17.47	9-13
	6x300x1000	90	K	15		466.31±5.45	463.82	50.93 ± 0.30	17.68	9-13
	6x300x600	120	E	5		329.90±7.04	278.29	30.95 ± 0.15	11.47	5-8
	6x300x600	120	E	15		344.60±8.98	278.29	31.09 ± 0.25	11.04	5-8
	6x300x1000	90	E	5		516.50±3.07	463.82	51.06 ± 0.30	17.63	9-13
	6x300x1000	90	E	15		537.58±15.19	463.82	51.39 ± 0.35	17.40	9-13

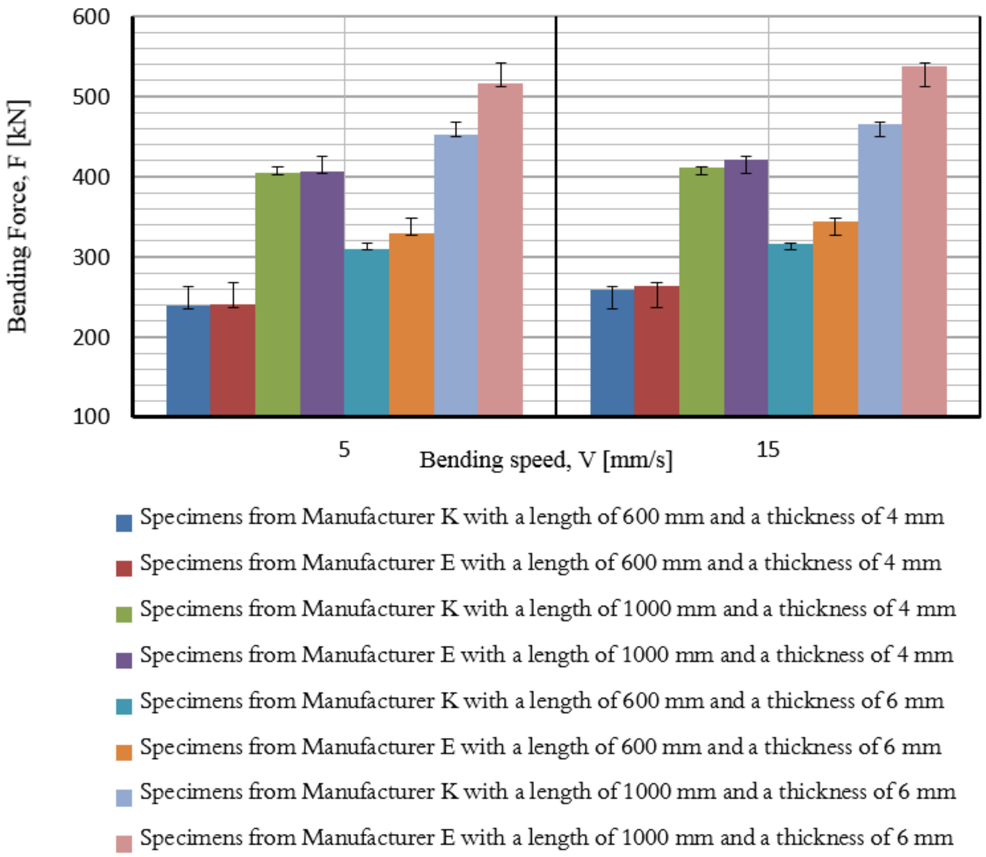


Figure 9:
Average bending forces of Hardox 400 steel plates from different manufacturers and dimensions with a forming speed of (a) 5 mm/s and (b) 15 mm/s

As seen in Figure 9, increasing the values of bending length, plate thickness and forming speed the bending force increased, too, noting that the exact values changed according to manufacturer. Approximately 60-70% increase in bending force was observed when bending length was increased from 600 mm to 1000 mm. In the case of plate thickness of whose value was raised from 4 mm to 6 mm, the average rise in force values was 15-30%. The least change in bending force was noticed for forming speed as 0,5-2,5% when it was raised from 5 mm/s to 15 mm/s which is due to the fact that at higher deformation speed, the strain hardening effect is more dominant.

4. CONCLUSION

Within the scope of this study, the effects of different parameters, namely plate thickness, plate length, bending angle, forming speed on bending behaviour of Hardox 400 steel were investigated. Bending force, upper die displacement and springback angle according to varying values of these parameters were identified. The results can be summarised as below:

1. By the tension tests, it was revealed that the mechanical properties of Hardox 400 steel vary according to the manufacturer from which it is supplied from. The difference between the measured mechanical properties and the ones supplied from the manufacturers had a direct influence on the bending properties, i.e., bending force, upper die displacement and springback values.
2. The bending forces obtained from Hardox 400 steel supplied from different manufacturers were not the same for the same plate dimensions. Unanticipated bending forces may affect the HPBTS and bending tools. Thus it should be considered that the mechanical properties supplied from manufacturers may vary according to the variation in chemical composition and production methods. Therefore, the machine manufacturers should prefer to do their own tests to identify the mechanical properties of the material.
3. The increase in bending length and plate thickness increased bending forces. Expectedly, when forming speed was raised, bending forces increased, too, which is basically due to strain hardening phenomena.
4. The measured springback angles were also found to vary compared to the values stated by the manufacturers. It should be taken into consideration that this may affect the machine and bending tools as well.
5. In the literature it was stated that bending forces increase linearly with the increasing bending length (Uckland et al. 2002). However, for Hardox 400 steel, it was seen that this increase was higher than a linear increase. Thus, if the relation between these two properties is assumed as linear, it may lead to errors in the design of machine and bending tools.

CONFLICT OF INTEREST

The authors confirm that there is no known conflict of interest or common interest with any institution/organization or person.

AUTHOR CONTRIBUTION

Fatih Aydemir worked on determination the conceptual and design processes of the study, management of conceptual and design processes, data collection, data analysis and interpretation, drafting the article, critical review of intellectual content, final approval and full responsibility.

Betül Gülçimen Çakan worked on data collection, data analysis and interpretation, and drafting the article, critical review of intellectual content, final approval and full responsibility.

Ali Durmuş worked on the determination of conceptual and design processes of the study, management of conceptual and design processes, data collection, data analysis and interpretation, critical review of intellectual content, final approval and full responsibility.

Kadir Çavdar worked on the determination of conceptual and design processes of the study, management of conceptual and design processes, data collection, data analysis and interpretation, critical review of intellectual content, final approval and full responsibility.

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