The Study of the Springback Effect in the UHSS by U-bending Process

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Abstract
Nowadays, the tendency by using the Ultra High Strength Steel (UHSS) in automobile industry has been increased in order to minimize the total weight of the car. The major problem by using of the UHSS in manufacture the automobile parts is springback. The objective of this research is to investigate the springback effect of the UHSS in U-bending process. In the experiment, the various forming parameters were conducted such as punch radius and blank holder force, the experimental materials in this study was JSC780Y, SPCN590R and JSC440W. According to the procedure, the experiment was conducted by specially designed of U-bending die, the U-shaped cross-sections refer to the NUMISHEET 2011, the benchmark for controlling the dimension of tool geometry. Springback angles after bending process were measured and calculated to springback factor for comparing and presenting the tendency of the springback effect.
As the experimental results, the influence of forming parameters found the increasing punch radius increased the springback angle while the increasing blank holder force decreased the springback angle. The springback factor value decreased when the springback angle increased. The results are showed the tendency of springback angles, which is useful for predicting springback effect of the UHSS.

Keywords*: Ultra High Strength Steel, Springback, U-bending process*

1 Introduction

Ultra High Strength Steels (UHSS) are finding acceptance in the automobile industry in Thailand, their increased strength to weight ratio can lead to increase fuel efficiency in vehicles. The major problems of stamping the automotive parts from UHSS are the increasing of springback due to high yield strength of the materials. The advantage of these steels is that they can provide higher strength to weight ratios for structural parts. Ultra High strength steels by definition have high strength of material which have more than 700 MPa, so it will require higher forces to form the parts [1]. Showed in figure 1.

Springback is a phenomenon that occurs in many cold working processes. While a metal is deformed into plastic region, the total strain is made up two parts, the elastic part and the plastic part. And when removing the deformation load, a stress reduction

will occur and accordingly the total strain will be decrease by the amount of the elastic part, there is a change part shape, which the result is the elastic recovery [2]. The study of this elastic recovery or springback phenomenon is very important issue that will influence and complicate the design of stamping dies for specific parts.

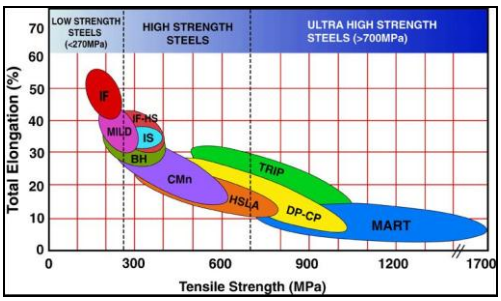


Figure 1: Steel classification chart of High Strength Steels (HSS) and Ultra High Strength Steels (UHSS)

T. Da Sisva Bolelho et al. studied springback phenomenon with the comparison of experiment and simulation. Mild steel and Hadfield steel were used for analysis which controlled blank holder force [3]. Ihab Ragai et al. studied the springback in strainless steel 410 focused on anisotropy effect of material. The process parameters were controlled such as blank holder force and friction [4]. M. Samuel investigated the effect of tool geometry and blank holder force on the final shape after springback. The study materials were Alluminium alloy, Mild steel and Strainless steel [5]. Bhadpiroon Sresomreong et al. studied the influence of die clearance on springback of High Strength steel JIS440 and JIS590 in U-bending process. The results from experiment were compared with simulation [6]. M. Kadkhodayan et al. investigated the influence of blank holder force on springback in U-bending by finite element program. The different values of blank holder force are preformed for Aluminium alloy and DP steel [7]. Carlos J. Gomes et al. studied springback behaviour in High Strength Steels using FEM. A U-shaped cross-section was analyzed and forming process is preformed in an explicit and implicit simulation [8] Springback depend on several variables such as material behaviour, thickness, plastic deformation level, die shape, friction and stamping process parameters [9].

The aim of this paper is to study of springback effect in Ultra High Strength Steel. The results show relationship between the springback effect and tool geometry (radius of punch) and blank holder force.

2 Instructions

2.1 *Materials*

All steels were supported by Summit Auto Body industry Co.,Ltd, JSC780Y 1.0 mm, SPCN590R 1.2 mm and JSC440W 1.2 mm were selected in this study, which the Ultra High Strength Steel (UHSS) was JSC780Y with the tensile strength value approximate 780 MPa and the High Strength Steel (HSS) were SPCN590R and JSC440W with the tensile strength values approximate 590 MPa and 440 MPa respectively, these steels with widely used in the automotive parts industry of Thailand. Table 1 shows the comparison of each steels standard. Role of anisotropy effect of materials, the rolling direction of workpieces were controlled at 0 deg. or along to the length of parts. Springback, the elastically-driven change of part shape after forming process, shaped profile will measure and compare the springback effect between each steels.

Table 1: The comparison of UHSS steel standards [10].

ASTM A607	JFS A2001	MES MM106	JIS G3135
Grade 45	JSC440W	SPCN440W	SPFC440
Grade 60	JSC590R	SPCN590R	SPFC590
Grade 70	JSC780Y	SPCN780Y	SPFC780

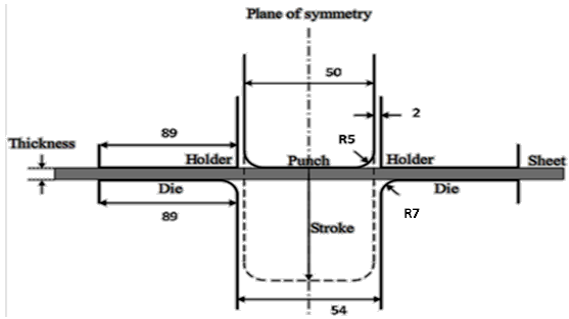


Figure 2: Details of NUMISHEET 2011 benchmark

2.2 *Geometry investigated*

Bending process was employed in this study, L-shaped, V-shaped and U-shaped which are widely used to investigation of springback phenomenon.

Several authors studied the springback effect of U-bending because the deformation of U-shaped is complex more than other shapes and this process is often used to manufacture sheet parts like channels, beams and frames. Their study used NUMISHEET benchmark for analysis springback as there is a standard method to measure springback angle in U-shaped geometry. In recent years, the U-shaped cross-section presented in NUMISHEET 2011 [10]. The dimensions of tool geometry show in figure 2.

Experiment was carried out by using a specially designed stamping apparatus. Figure 3 shows the details of the actual geometry investigated in this study, which used to measure springback angle.

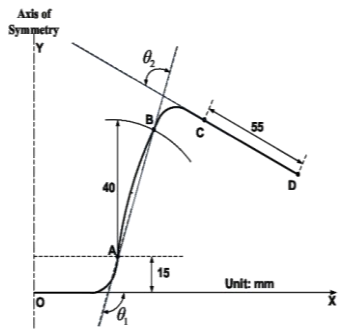


Figure 3: Measurement parameter for springback

2.3 *Experimental procedure*

All of experimental study was conducted on the MTS810 hydraulic testing machine, that will be used for the experiments is a single-action press with a capacity 250 kN.

The schematic drawing in figure 4 shows the setup, which consists of a die, a punch, a blank holder, and upper and lower platens, which are separated from the blank holder by springs. The blank holder can move up and down freely on the two guide posts attached to the lower plate. The lower-springs hold the blank holder at a small distance for die surface, for very easy insert the blank to the die. The upper-springs are used for the transmission of blank holder force. The insert punch was designed for changing the radius of punch in this study. The guide posts and guide bushes, standard parts were used that could provide perfect fit. The four pins for spring guides were attached to the lower plate. The die and the lower plate are fixed to the hydraulic ram after alignment with the punch.

The three plates were made from S50C. The insert punch and the die were from SKD11, which were heat-treated by Nitriding to increase its surface hardness to 58 HRC, and was Hard chrome process its hard chrome plating thickness was 50 µm.

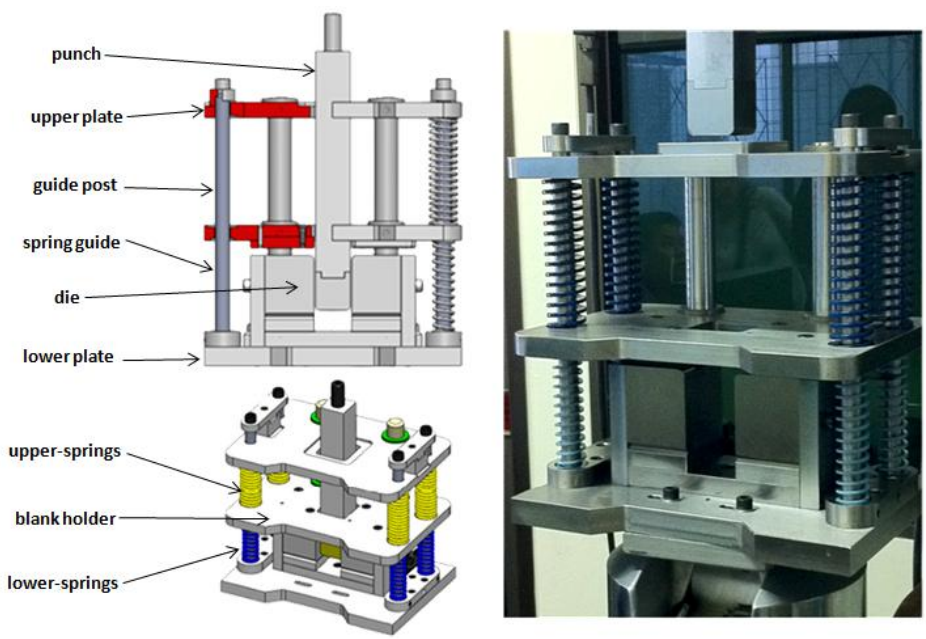


Figure 4: U-bending die experimental apparatus.

After placing the blank holder on the die, the upper plate is pressed against the blank holder force. When the required blank holder force was reached, the spring height was fixed to constant the force. The insert punch was moves down until its stroke reaches 71.8 mm, then moved up, punch speed was 1 mm/s, radius of punches were 3, 5, 8 mm. The blank holder force maintained at 3000, 4500 and 6000 N. The blank size was 360 x 30 x thickness mm.

Figure 5 shows workpieces of the U-bending process. Springback angle, it was found the highest angle was JSC780Y and the smallest angle was JSC440W. Springback measurement $\theta_1$and θ_2 are then taken on the formed part using a coordinate measuring scheme with NUMISHEET 2011 benchmark.

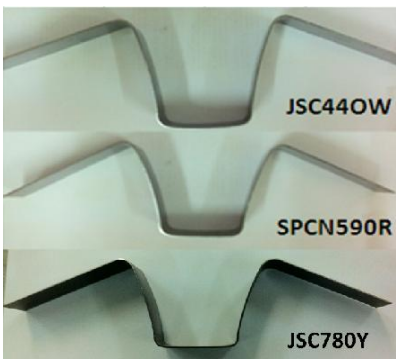


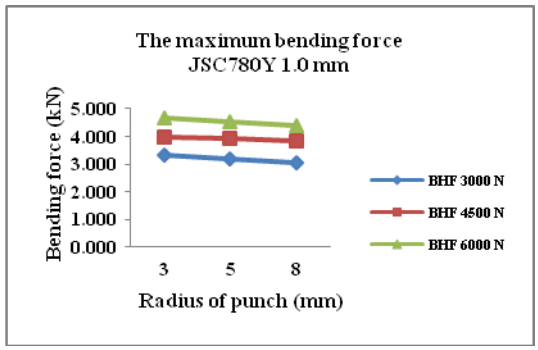
Figure 5: Workpieces after springback with the blank holder force 3000 N and the radius of punch 5 mm.

3 Result and disscussion

3.1 *Bending force*

Figure 6 shows the relationship between bending forces and radius of punch at 3, 5 and 8 mm with varied blank holder force 3000, 4500 and 6000 N. Bending force, it was started bending process when the punch contacted the blank surface and move down. Maximum bending force, the bending force level was increasing because sheet metal were deformed into elastic region until maximum bending force which referred to the highest force at the highest graph diagram level, at this point sheet metal deformed into plastic region their bending process completed in work piece.

The experimental results were compared among three materials, the SPCN590R presented the highest maximum force following by JSC780Y and JSC440W respectively. Increasing the yield strength of material increased the forming force of workpiece.



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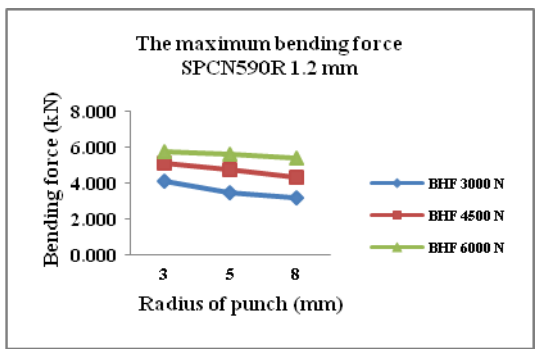

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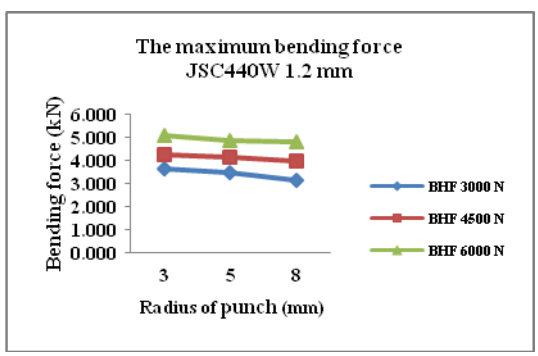

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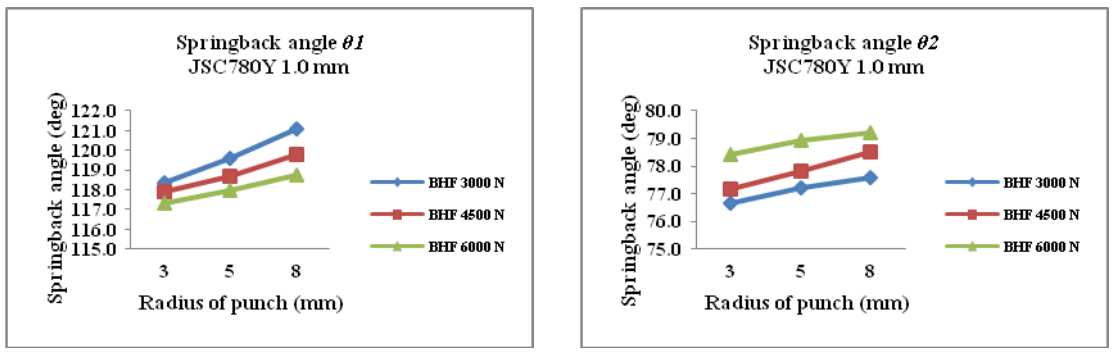
Figure 6: The comparison of maximum bending force (a) JSC780Y, (b) SPCN590R and (c) JSC440W

The influence of the radius of punch in bending process at the same blank holder force revealed that the increasing of punch radius decreased the maximum bending force, due to the obstruction of materials flow in small radius area.

And the influence of blank holder force was found that the increasing of blank holder force increased the maximum bending force, because the application of a higher blank holding prevents the workpiece from sliding easily between the blank holder and the die.



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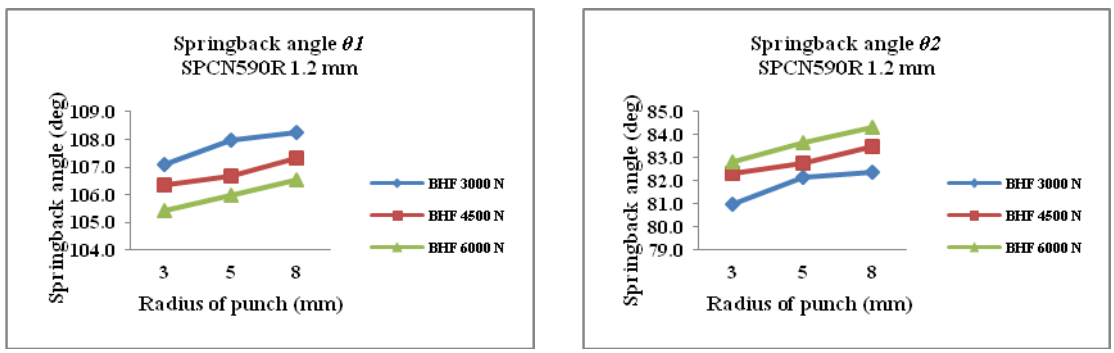

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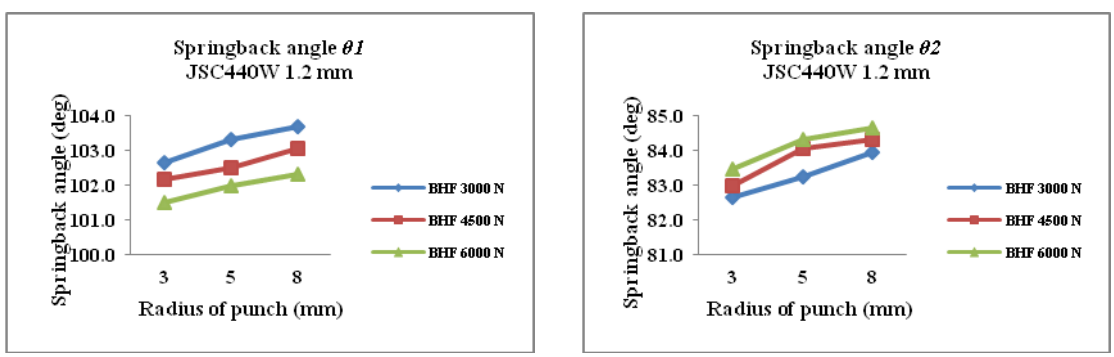

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Figure 7: The relationship between springback angle and variable parameters (a) JSC780Y, (b) SPCN590R and (c) JSC440W

3.2 *Effect of punch profile radius (Rp) on the springback*

The springback of workpieces after die removal were measured by measurement device, a angle protractor with the accuracy 0.5 deg., in this study consider springback angle at θ_1 and θ_2. For the ideal case of no springback effect, the angle θ_1 and θ_2 are respected to be 90 deg. As amount of springback angle increased at workpiece, it found θ_1 increased (> 90 deg.) and θ_2 decreased (< 90 deg.).

Figure 7 shows the springback angle in workpiece, springback angle θ_1 increased as the radius of punch increased. And the higher yield strength material the greater elastic return resulting in the higher springback angle. From all material the springback angle of JSC780Y was the highest following by

SPCN590R and JSC440W respectively. Because decreasing the radius of punch will increase the stretching in material, and consequently extend the region of plastic deformation to be more uniform through the thickness, increasing plastic strain will decreased the elastic recovery or springback.

3.3 *Effect of blank holder force (BHF) on the springback*

Workpieces were tested by varying the blank holder force from 3000 to 6000 N. It was found increasing the blank holder force causes a decreasing of the springback angle (θ_1) shows in figure 7. At constant radius of punch which the increasing of blank holder force will decrease springback angle. And the same tendency of the results in all materials. Because the increasing of blank holder force will become tension force in the material cause of the increasing plastic deformation. Stretching and thickness reduction occurred means springback will decrease.

3.4 *Springback factor (K_R)*

In order to accurately compare springback results for three materials, both analyses were conducted using same operation conditions. The experimental results were based on three samples for each condition. For ideal case of no springback, the wall of the U-shaped is expected to be flat, the angle θ_1 and θ_2 are expected to be 90 deg. Springback factor, commonly denoted by K_R, is the relation between the initial and final angle. K_R = 1 means there is no springback, where a value of 0 means total springback. K_R depends on the material characteristics and the ratio between bending radius and sheet thickness shows in figure 8.

$$K_R = \frac{\alpha_2}{\alpha_1} \quad (1)$$

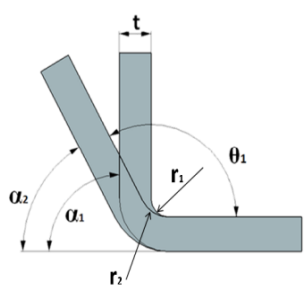
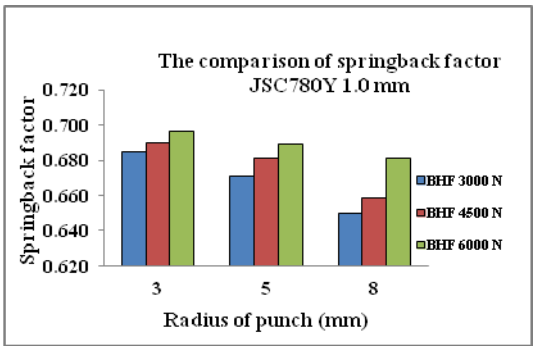


Figure 8: Springback factor



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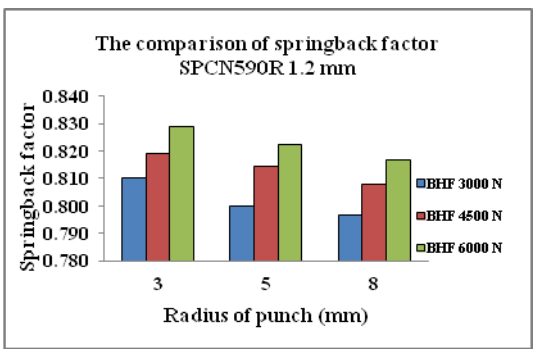

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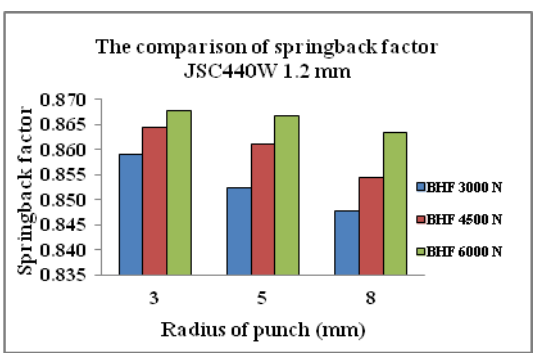

(c)

Figure 9: The relationship between springback factor and variable parameters (a) JSC780Y, (b) SPCN590R and (c) JSC440W

Where α_1 is bending angle, α_2 is designed angle at workpiece (springback angle) [11]. Figure 9 shows the comparison of springback factor of each materials. At same R_p that the larger yield strength the greater elastic return, therefore its springback factor is very low ($K_R < 1$). JSC780Y, the highest yield strength of material cause of the lowest K_R values.

The variation of the radius of punch were 3, 5 and 8 mm, it was found that increasing of the radius of punch decreased springback factor values due to springback angle increased. The varied of blank holder force from 3000, 4500 and 6000 N, the K_R increased when the blank holder force increased.

4 Conclusions

This paper has provided a summary of experimental study of springback effect in the Ultra High Strength Steel (UHSS) compare with the conventional High Strength Steel (HSS). The workpiece in this study, UHSS was JSC780Y and HSS were SPCN590R and JSC440W. The bending process was selected to the experiment with the NUMISHEET 2011 benchmark, there is standard method to measure the change of workpiece after forming cause of springback effect.

Springback depend on material properties especially the level of yield strength values. The expeimental result showed springback effect of UHSS was higher than HSS.

Increasing plastic strain of material that's the way to decrease springback effect. The U-shaped bending experiment with varied radius of punch and blank holder force, it was found the strain increased as the radius of punch decreased while blank holder force increased.

Springback factor (K_R), the results showed tendency of springback phenomenon, which is useful for predicting springback effect of all materials. The higher K_R valuve means the changing of workpiece after forming is less or low springback. Decreasing the radius of punch and increasing the blank holder force will increase K_R valuve.

5 References

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