American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-5, Issue-9, pp-194-201
www.ajer.org
Research Paper Open Access

Numerical and Experimental Heat Transfer

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ABSTRACT: *This research work deals with the implication of modern retailing at not only in Dhaka, Bangladesh but also the whole district in Bangladesh with main objectives to find out technological activity, impact on modern welfare..*
Keywords: *Microstructure, Thermo-mechanical, Coating, Rectengular, Blank holder*

I. INTRODUCTION

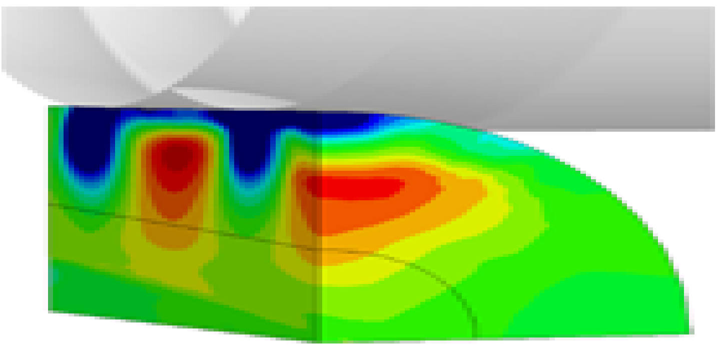
When producing thin ultra high strength steel components with the press hardening process, it is essential that the final component achieves desirable material properties. This applies in particular to passive automotive safety components where it is of great importance to accurately predict the final component properties early in the product development process. The transfer of heat is a key process that affects the evolution of the mechanical properties in the product and it is essential that the thermal contact conditions between the blank and tool are properly described in the forming simulations. In this study an experimental setup is developed combined with an elementary inverse simulation approach to predict the interfacial heat transfer coefficient (IHTC) when the hot blank and cold tool are in mechanical contact. Different process conditions such as contact pressure and blank material (22MnB5 and Usibor 1500P) are investigated. In the inverse simulation, a thermo-mechanical coupled simulation model is used with a thermo-elastic-plastic constitutive model including effects from changes in the microstructure during quenching. The results from simulations give the variations of the heat transfer coefficient in time for best match to experimental results. It is found that the pressure dependence for the two materials is different and the heat transfer coefficient is varying during quenching. This information together with further testing will be used as a base in a future model of the heat transfer coefficient influence at different conditions in press hardening process.

II. HEADINGS

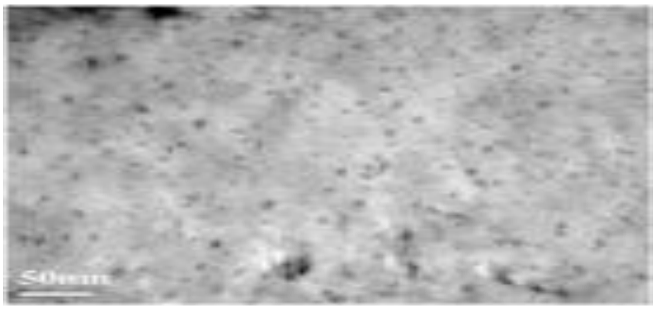
Effect of processing route on the microstructure, tensile properties, and wear behavior of DP steels is investigated. The DP steel with fine and fibrous marten site, obtained from IQ heat treatment, exhibits the highest values of UTS and TE. The wear resistance of produced DP steels changes in the order of SQ < IA < IQ.

III. INDENTATIONS

A modeling methodology is developed to assess the risk of hot-tearing in round billets, consisting of a thermo-mechanical model followed by the codification of failure criteria. A cracking indicator is then obtained and applied to evaluate the effect of pinch-roll compression. Finally, influence of operative variables on the cracking risk is analyzed. Model results present a good agreement with cracked bar macro-etchings.



Effect of in situ nano-particles produced in melt directly is investigated here. On the one hand, these in situ nano-particles present coherent or semi-coherent relationship with the matrix, which allow of a substantial improvement of the strength while without sacrificing its plasticity and toughness too much. On the other hand, the as-cast structure is obviously optimized due to the heterogeneous nucleation effect of these in situ nano-particles.



A new method for manufacturing Mn18Cr18N steel has been developed based on hollow ESR ingot. A mathematical model of ESR hollow ingot based on the CAFE method has been developed to reveal the morphology of the grain growth and the evolution process of the macrostructure. The optimized technical parameters have been summarized based on the simulation and experiment results.

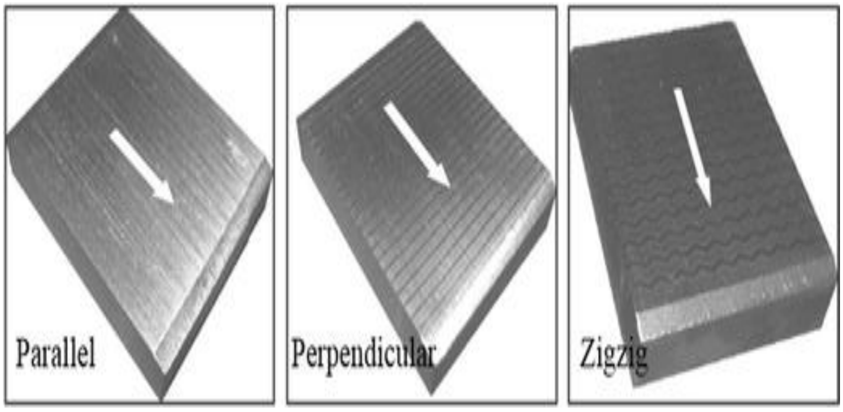
In recent decades, the use of high- and ultra high strength steels in modern car bodies has increased drastically. This is due to both severe legislation of passenger passive safety and the recent year's effort to reduce fuel consumption to decrease environmental harmful emissions. Many new materials and technologies have been developed to meet these new demands, where press hardening, or also called hot stamping, has been one of the most successful technologies to produce complex components with superior mechanical properties. In the product development process, thermo-mechanical coupled forming simulations are used to predict the final components properties. In order to obtain accurate results, correct models of the physics involved in the simultaneous forming and quenching is needed. The objective of current work is to investigate the heat transfer between the hot blank and the cold tools in the press hardening process. The transfer of heat is the key process that affects the products formability, final geometry, residual stresses and the development of mechanical properties. The two most important contact criteria are investigated in this thesis, heat transfer at a thin contact gap and heat transfer at mechanical contact under an applied contact pressure. An experimental setup to investigate these two contact criteria is developed. It consists of an upper and lower cylindrically shaped tool were the hot blank is quenched between cold tool surfaces. The results from experiments consist of measured temperature histories in the tools. A finite element model of the experiments in combination with an inverse simulation algorithm is used to predict the heat transfer at each contact condition. The inverse technique called improved advance retreat and golden section method is used to solve the ill conditioned inverse heat conduction problem that arise when solving for the heat transfer at the contact interface. The result from inverse simulations in combination with regression analysis is used to develop a general model of the heat transfer coefficient. The outcome is two regression models, one for each contact criterion, were the parameters affecting the heat transfer coefficient are identified. It is found, that a heat transfer coefficient depending on contact pressure or contact gap as well as contacting surface temperatures provide a good match between experimental and simulated temperature response in the tools. The regression model captures the main characteristics of the heat transfer coefficient and has been implemented as a subroutine in the finite element code LS-DYNA.

It is of significance to evaluate the equivalent contact heat transfer coefficient (ECHTC) at the sheet-die interface in hot stamping of boron steel (HSBS) for controlling the local cooling rate of the sheet and hence obtaining components with tailored microstructure and properties. Moreover, accurate evaluation of the ECHTC can provide a reliable thermal boundary condition for numerical simulation of the HSBS process. In the study, a simple and effective physical simulation setup for die quenching of boron steel (DQBS) was developed, where the temperatures at measurement points are related only to the ECHTC so as to improve the evaluation accuracy. A FE-based optimization model for inverse evaluating the ECHTC was established. The ECHTCs at the B1500HS sheet-H13 die steel interface were identified under various contact pressures, and it was found that the ECHTC increases exponentially with the pressure increasing. Both the physical simulation of DQBS and the HSBS experiment were performed to verify the ECHTC evaluated, and the maximum relative errors of 9.6 and 19.7 % were observed, respectively, between the predicted and measured temperature histories.

The thermal and tribology properties at the tool/work-piece interface significantly affect the draw-ability and formability for hot stamping processes. Although these properties have been extensively investigated for the hot stamping of high strength steels, there has been limited research into the effect of these properties for hot stamping of aluminium alloys and in particular for forming with HFQ conditions. With regard to reducing the friction coefficient at the tool/work-piece interface, the use of lubricants can enhance the ability to produce a good quality component. To increase the effect of a lubricant treatment, a variety of surface engineering methods, such as diamond-like coatings (DLC) and micro-scale texturing, have been applied to tool surfaces. The DLCs act as solid lubricants and simultaneously increase wear resistance and reduce friction. Wank et al investigated the capacity of DLC coatings in lubricant free cold massive forming of AA6016, the results showed that the capacity of DLCs depended strongly on tool surface roughness. Heinrichs et al. also demonstrated the cold forming of aluminium alloys including AA6082, where less material transfer between the tool and aluminium alloy work-piece occurs when a more advantageous topography is used with polishing the interfaces.

Texturing is another feasible approach to enhance the lubrication effect. Costa and Hutchings found friction was greatly reduced when a tool surface was patterned with grooves perpendicular to the drawing direction in strip drawing processes. These grooves were believed to act as lubricant reservoirs to enhance the lubrication effect. Similar studies have also been conducted by Qiu et al. to investigate the texture patterns on friction coefficient. Kovalchenko et al. studied the frictional and wear behaviour of textured tool surfaces in the lubricated condition, using laser surface texturing, where friction coefficient is reduced in conformal and relatively low-pressure lubricated contacts. Research has also been conducted on the friction coefficient using textured forming dies in metal forming process. In addition, to evaluate the thermal effect of textured tool surfaces, Xie et al. performed experiments using multi-scale-structured surfaces and spray cooling, where a 65 % heat transfer enhancement was determined. Moreover, tool surface textures have been used to obtain a tailored strength distribution on the formed part, as patented by Gestamp Hardtech for press hardening operations.

However, these extensive studies on the surface texturing were mainly focused on the texture dimensions at micro-scale. In practical stamping processes, the tool dimensions are normally at meter scales and macro tool surface texture could affect the frictional property and heat transfer significantly, and thus the flow and draw-in of materials in hot stamping. Compared with micro-scale surface textures, little research has been carried out on macro-scale surface textures for stamping. Franzen et al. investigated friction coefficient at the tool/work-piece interfaces using selective texturing on the tool surfaces as shown in Fig., a significant increase in friction coefficient was found due to the material elastic deformation near the texture area and local plastic deformation on the sheet surface. Kleiner et al. investigated the friction behaviour of sheet metal in strip drawing tests using tools with different milled surfaces. The textures were oriented along and across the material flow direction and in different zigzag directions. The friction coefficient was clearly increased in the zigzag direction, while linear textures, parallel to the drawing direction, do not increase compared to non-textured, grinded tool surfaces.



Commercial AA6082-T6 condition aluminium sheets with a thickness 1.5 mm were used as test-pieces. The chemical composition is provided by the materials supplier and given in Table 1. The typical solution heat treatment temperature for the alloy is 525 °C.

Table 1 Chemical composition of AA6082

Element	**Mn**	**Fe**	**Mg**	**Si**	**Cu**	**Zn**	**Ti**	**Cr**	**Al**
%	0.4–1.0	0–0.5	0.6–1.2	0.7–1.3	0–0.1	0–0.2	0–0.1	0–0.25	Balance

Rectangular test-pieces with dimensions: 240 mm length and widths of 86, 90, and 94 mm were produced by laser cutting. For the cold stamping tests, test-pieces were tested in the annealed condition by heating the as received T6 material to 415 °C and soaking for 1 h and subsequently furnace cooling. Hot stamping test samples used were the received T6 condition and tested under HFQ conditions by first solution heat treating at 525 °C for 2 min.

In order to perform the top-hat drawing tests, a tool was mounted onto a 1MN ESH hydraulic press with a maximum forming speed of 600 mm/s and a total stroke of 100 mm. The tool used for the tests is shown in Fig. 2a. As can be seen, the top-hat shaped die is attached to the ram whereas the rectangular punch is fixed to the base of the tool. Rectangular blank-holders (120 × 100 mm) for locating the test-piece material are positioned on either side (both left and right) of the punch and are secured to the middle plate of the tool. The blank holders can be replaced with blank holders of varying textures in order to test macro-texture effects on drawing. Moreover, located above the blank holder and secured to the die are inserts located on both the left and right hand side of the die. As with the blank holders, these are replaceable and allow different textures and surface treatments to be applied without the need to machine multiple dies. The material used for the punch and die was H13 tool steel whereas G3500 cast iron [34] was used for the blank holders and inserts.

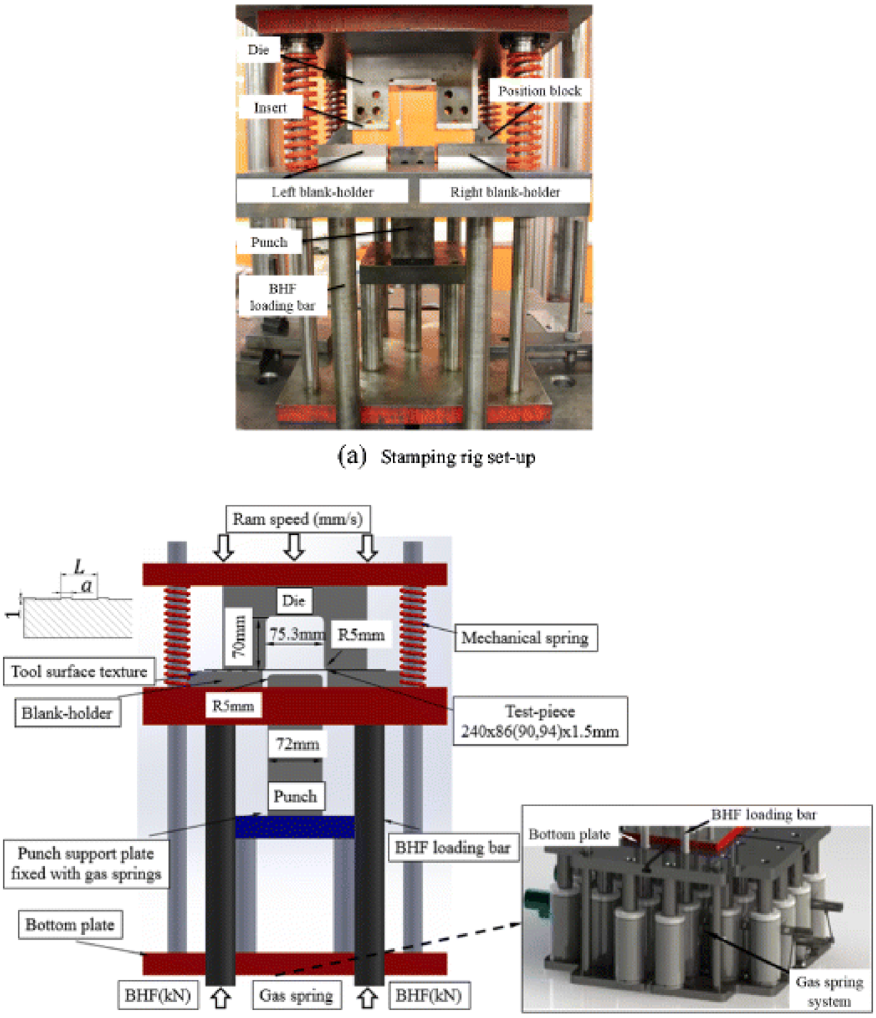
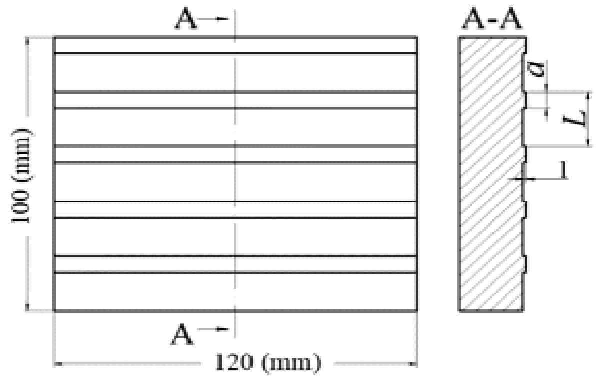
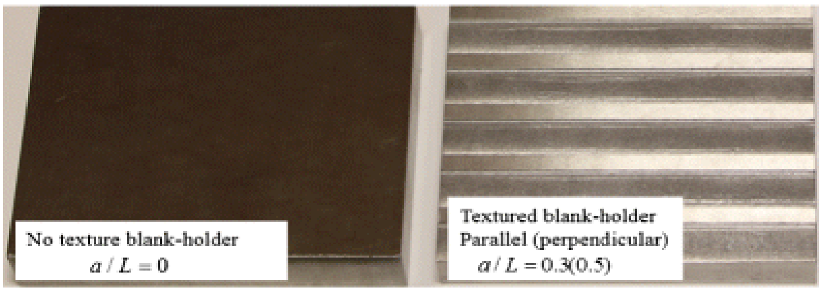


Fig. 2 The stamping test rig design and set-up details

During testing, the test-piece is positioned onto the blank holders. The ram subsequently moves downwards closing the gap between the die and blank holders. Once the die is in contact with the blank holders, the assembly moves down over the stationary punch which subsequently draws the material into the die. During the entire forming process, the blank holding force can be adjusted through the use of blank holding force bars attached to a gas cushion positioned beneath the tool. By altering the pressure of the gas spring system located beneath the test rig, the blank holding force and in-die quenching force can be varied. In this system shown in Fig , there are a total of 28 gas springs, with a maximum extrusion load of 50 kN. This gas spring system can be divided into two groups. The first group consists of four gas springs connected to the blank holding force bars in order to support the middle plate and supply the blank-holding force. The second group consists of the remaining 24 gas springs which support the bottom plate of the test rig, and provide the in-die quenching force for the formed component.



(a) Tool surface texture definitions



(b) Manufactured tool surface textures

The effect of macro-scale textures on the draw of material were tested by applying textures of depth 1 mm onto the blank holders as shown in Fig. A texture ratio a/L was defined, where a is the width of the texture and L is the distance between the beginning of one texture to the beginning of the subsequent texture. In this case, a value of $a/L = 1.0$ indicates no texture i.e., full contact between the test-piece and the blank holder surface whereas $a/L = 0$ indicates a knife-edge contact to the test-piece. For the purpose of work conducted in this paper, texture ratios of 0.3, 0.5 and 1.0 were used which were machined onto the blank holders through the milling process as in Fig. In order to assess the effect of texture direction, the above texture ratios were machined onto the blank holder in both the parallel and perpendicular direction to the material draw.

For the performance of cold stamping tests, the test-piece material was first annealed according to the process presented in "Material and test-piece". Moreover, a range of texture ratios and texture orientations of $a/L = 0.3$, 0.5 and 1.0 in both the parallel and perpendicular direction were tested. The tests were performed by maintaining the texture ratio of the right-side blank holder as $a/L = 1.0$ whilst varying the textures on the left-side blank holder. By positioning different blank holders on each side, the amount of material drawn from each blank holder will vary, which allows the effect of the textures to be assessed. Moreover, in order to assist material flow, Omega 35 lubricant was applied evenly on both blank holders, punch and die insert surfaces.

For hot stamping tests, the test-pieces were solution heat treated at 525 °C for 2 min and quickly transferred to the tools and formed within 7 s resulting in a maximum temperature loss of no greater than 55 °C, in order to maintain the temperature above the precipitate formation temperature. Finally, the formed top-hat shape was quenched within the cold dies to room temperature. The blank holder ratios and orientation used for the tests were the same as those of cold stamping. In addition to varying texture design, hot stamping tests involved the variation of blank-holding force at 5, 10 and 15 kN. The ram speed was fixed at 150 mm/s.

As stated above, varying the texture of the left blank holder whilst maintaining a constant texture on the right blank holder will affect the material draw on each blank holder. This can be quantified by assessing the length of the flange region material. In order to reflect the flange difference on the two sides, a flange ratio ζ can be defined as a ratio of the lengths of the two flange regions as shown in Eq. (1).

$$\zeta = L_{left}/L_{right} \quad (1)$$

Where L_{left} is the flange length of the formed part corresponding to the left-hand side blank-holder, L_{right} is the flange length of the formed part corresponding to the right-hand side. The flange length is defined as the distance between the flange edge and the edge of the radius on the formed part. As there may be variation of flange length through the depth of the part, the flange lengths are calculated as the average value between the front and the back to minimize the geometry error as shown in Fig. 4a.

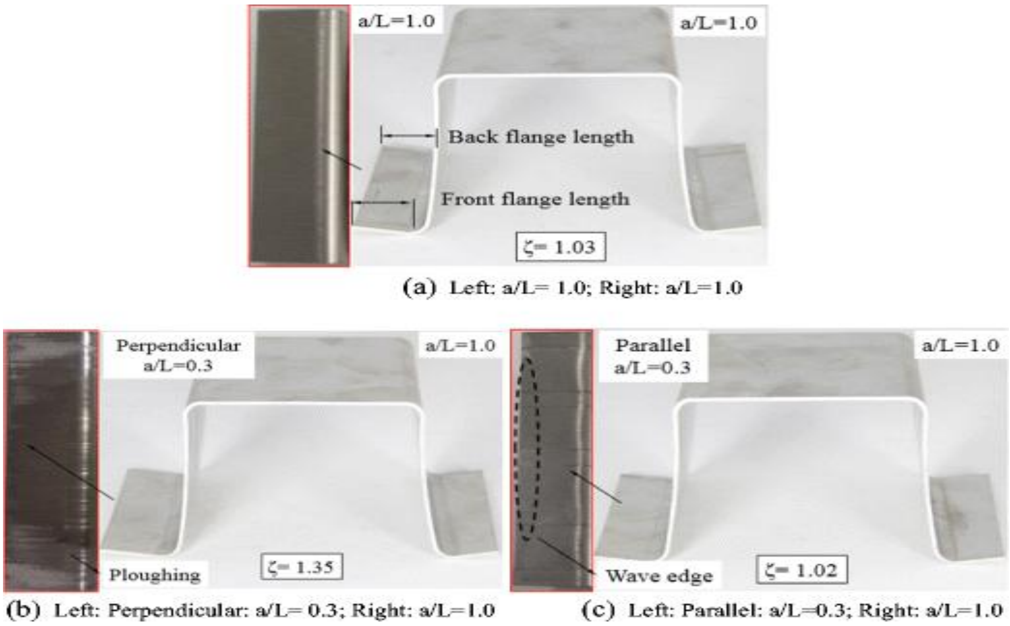


Fig. 4 Texture orientation effect on the draw-ability and part quality with a blank-holding force 10 kN for cold stamping processes

Figure 4 presents cold stamped parts with tool textures: (a) no surface texture $a/L = 1.0$, (b) perpendicular texture $a/L = 0.3$ and (c) parallel texture $a/L = 0.3$ on the left-hand side blank-holder, while the right-hand side blank-holder was fixed with no texture ($a/L = 1.0$). The flange ratio ζ in Fig. 4b increased to 1.35, compared with 1.03 shown in Fig. 4a, which indicated that the material on the left-hand side of (b) was constrained from being drawn into the die, hence resulting in a longer flange length on the left blank holder. Examination of the underside view of the flange regions (Fig. 4a) shows a smooth surface finish whereas the region of Fig. 4b involving the perpendicular blank holder shows an obvious ploughing effect. This is due to the texture edge applying a constraining effect on the deformed material as illustrated in Fig. 5 and caused scratches on the flange area as shown in Fig. 4b. As shown in Fig. 5, when a blank-holding force is applied on the blank using a perpendicular texture orientation, the blank material is deformed elastically and a relative thickness variation will occur with the texture edge constraining material draw and causing the ploughing phenomena.

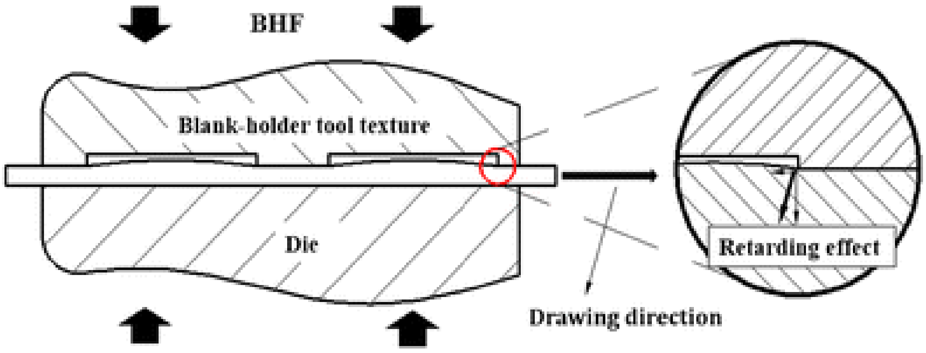
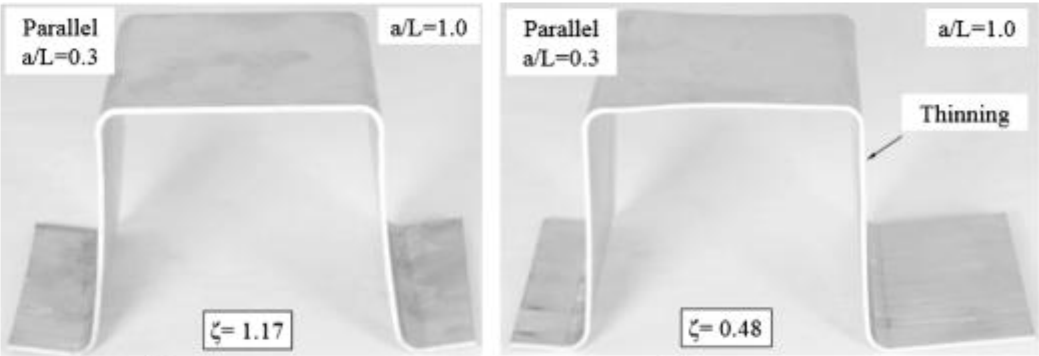


Fig. 5 Illustration of the ploughing effect on the material drawing using the perpendicular tool texture

Figure 4c shows the formed part using a parallel texture $a/L = 0.3$, where the flange ratio ζ was 1.02, which is not a significant change compared with Fig. 4a. This indicates that that the ploughing effect is not obvious when the texture orientation is aligned in the parallel direction to material flow. Material deformation could still be observed on the underside view of the contact surface. Another typical characteristic of the parallel texture is the wave profile at the outer edge of the flange resulting from friction force distribution. Material in contact with the blank-holder was constrained by friction whereas material located above the groove of tool texture was free to flow.

Effect of tool texture feature

With regard to the constraining effect of perpendicular tool texture on the material draw, cold and hot stamping using parallel tool textures with different texture ratios were conducted. Parallel tool texture blank holders (Left: $a/L = 0.3$ and Right: $a/L = 1.0$) were used with blank-holding forces of 30 kN when performing cold formed components and 15 kN for hot formed components. For the cold formed part shown in Fig. 6a, the flange ratio ζ was 1.17, a 13.6 % increase from that in Fig. 4a, which might illustrate that, the parallel tool texture had a constraint effect at large blank-holding force, but not as severe as the perpendicular texture.



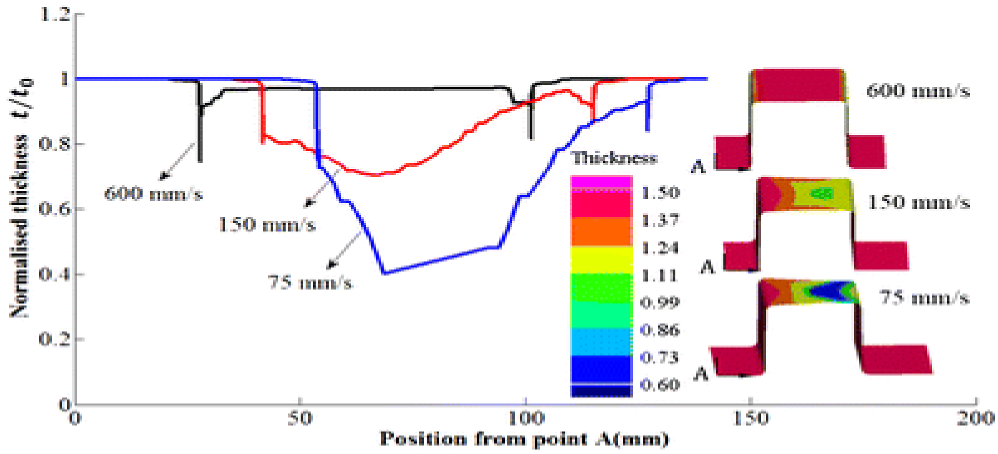
(a) Cold formed part (b) Hot formed part

Fig. 6 Effect of tool texture design on the draw-ability in the stamping processes. The tool texture designs are: *Left*: Parallel a/L = 0.3; *Right*: a/L = 1.0 with blank-holding forces **a** 30 kN and **b** 15 kN

Figure 6b shows the hot formed part using the same tool texture design with Fig. 6a. The flange length on the left-hand side (parallel $a/L = 0.3$) was much shorter than the right-hand side ($a/L = 1.0$). The flange ratio ζ was significantly decreased to 0.49, which illustrates that surface texture has a significant effect on improving the draw-ability in hot stamping. Regarding the non-uniform temperature field of the test-piece, temperature of the punch nose region was higher than that of flange area. As the material strength is higher at lower temperatures, the strength of straight side wall and flange area material is higher than the punch nose area material. Due to this, deformation may concentrate on the high temperature region which might cause failure to occur once necking occurred at a higher blank-holding force. Using a blank-holder with surface texture on the left-hand side, the contact area becomes much smaller compared with the full contact case of the right-hand blank holder. Hence, the flange area temperature of the left flange would be much higher, and closer to the punch nose temperature when compared to the large temperature difference between the punch nose area and the flange area on the right side using the non-texture blank-holder. Therefore, the lower temperature difference on the left-hand side might contribute to a more uniform material deformation and avoid the concentrated material deformation at the punch nose area. Further analysis will be given according to FE simulation results presented in the following sections

Effect of forming speed

Figure shows the effect of forming speed on the normalized thickness distribution of hot stamped parts for a given tool texture design: Left: parallel $a/L = 0.3$, Right: $a/L = 1.0$. Three forming speeds, 75, 150 and 600 mm/s, were chosen to investigate the effect of forming speed on the draw-ability in hot stamping using macro-texture tools. A section is located on the centre-line of the part, taking the outside edge of the left side flange as the origin. The normalized thickness distributions for forming speeds 150 and 75 mm/s have a similar trend, the maximum thinning is located at the top surface (punch nose section), shifting to the right side for this blank holder combination. Normalized thickness increased with increasing forming speed, which means less thinning occurs at a higher forming speed. This can be explained by the influence of forming speed on material hardening, where the hardening effect is greater at high forming speeds due to the strain rate effects on forming the visco-plastic alloy. In addition, a higher forming speed reduced the contact time between the tool and test-piece and thus heat loss was reduced, resulting in a temperature that was higher and more uniform and hence leading to higher ductility and more uniform flow. As shown in Fig. at a forming speed of 600 mm/s, the hot stamped part had no obvious necking, unlike the parts formed at 75 and 150 mm/s. High speed thus enhances the isothermal nature of the process



The work described in this paper has investigated the effect of rectilinear macro-textures on metal flow in the cold and hot stamping of a top-hat shape; a channel with flanges. Perpendicular tool textures corresponding to the material flow direction had constraint effect on material flow as the material deformation due to the large blank-holding force, the flange ratio was increased to 1.35, compared with 1.03 using non-texture on the two sides in cold stamping process.

In hot stamping processes, a texture parallel to metal flow can significantly improve draw-ability. Good agreement exists between FE computed and experimental flange ratios and normalized thickness distributions. The minimal flange ratio was 0.46 for $a/L = 0.3$ in comparison with the full contact case $a/L = 1.0$ at a BHF 15 kN and forming speed 150 mm/s, which verified the improved draw-ability using macro-texture tools.

The improved draw-ability is mainly due to the non-uniform temperature field generated by the macro-tool texture at the flange area. Using such kind of macro-tool texture, simulation work has shown that the temperature of the test piece drops from the initial temperature 470 to 302.2 °C (35.7 %) on the left-hand side ($a/L = 0.3$) and 124.6 °C (73.5 %) on the right-hand side ($a/L = 1.0$). With the decrease of texture ratio, the lower contact area contributed to a higher test-piece temperature which was reflected by decreasing flange ratio.

IV. CONCLUSION

Limitation:

1. Significance to evaluate the equivalent contact heat transfer coefficient (ECHTC) at the sheet-die interface in hot stamping is only on boron steel.
2. In hot stamping processes, a texture parallel to metal flow can significantly improve only on draw-ability.

Though it has limitations but modern era is very dependable on these. Specially in pharmaceutical sector these are very effective. Hence, all kinds safety for human is possible by this system. So, this system is absolutely welcome for modern era.