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The Influence of Friction Conditions on Formability of DC01 Steels by ISF

Elif Malyer[1], Hikmet Sadi Müftüoğlu[2]
[1]*(Machine and Metal Technologies Department, Turgutlu Vocational School/ Celal BayarUniversity, Turkey)*
[2]*(Engineering Sciences Department, Institute of Natural and Applied Science / Celal BayarUniversity, Turkey)*

Abstract : *The present study has been undertaken in order to investigate the suitable tool and lubricant that could be employed to form DC01 steel sheet by negative incremental sheet metal forming. For the intended aim, various combinations of coated and uncoated tools and lubricants were used. The effect of each combination of tool and lubricant on the quality of forming parts was studied by measuring the thickness and geometric accuracy of the parts. It is obtained that the geometry of samples formed by the tool has the maximum friction coefficient could not reach the target model geometry. The best geometric accuracy was obtained on sample formed by the CrCN coated tool with the lubricant has good lubrication performance. The best lubricant confirmed as forming and drawing oil with the highest viscosity for the forming condition using an uncoated tool.*

Keywords : *DC01, Geometric accuracy, Incremental forming, Lubrication, Coating*

I. INTRODUCTION

Cold rolled, non-alloy DC01 (Erdemir 6112) steel sheet metal is being extensively used for in the automotive industry, manufacturing household, refrigerator and washing machine. Presently, press forming, such as, drawing, bending, etc., is the common process in practice to form the DC01 steel sheets. Most of the existing forming processes are feasible for large batches [1]. At the same time, development of the technology for small lot production is required in industry [2]. Incremental sheet metal forming (ISF) which is developed with the aim to decrease the set up costs of sheet metal forming, prototyping and to increase the process flexibility and formability of sheet metal is one of the newly developed technology for that purpose [3, 4, 5, 6].

ISF can form sheets have high formability into three-dimensional shape with large deformation. However, it is difficult to form sheets have low formability, such as, high strength aluminum alloy [2]. On the other hand, ISF is a slow process and has formability limits. To improve formability limits and process time, developing studies have been continued. Most studies are based on the thickness of the sheet, size of vertical step down per revolution, speed and radius of the forming tool [6-12]. However, friction condition is one of the main parameter influencing the part geometry, sheet thickness distribution, surface roughness and also, forming time. The main goal of the ISF operation is finding proper process temperature generated during forming operations for the forming parameters that decrease the forming time. In the present study, DC01 steel alloy sheets were formed by negative ISF. The formability of material, effects of lubrication conditions and coating aspect of the tool on forming process were studied. Observation of geometric accuracy and thickness distribution of forming parts was also carried out.

II. EXPERIMENTAL SETUP

The commercial DC01 steel sheet metal with one millimeter thickness was used for incremental forming. The chemical composition which was determined according to spectral analysis and mechanical properties of material determined according to tensile tests are given in Table 1 and 2, respectively. The samples were cut by laser cutting. A three axis CNC milling machine was used to form a frustum cone of which dimensions are given in Fig. 1 by Negative ISF. The sheet metal blank was clamped on the support that was designed and manufactured for Negative ISF. The assembly view of support is given in Fig. 2.

UGNX3 CAD/CAM software was used for the tool path generation. The helical tool path strategy was preferred for the forming experiments. In this strategy, a guideline is drawn between the top and the bottom center of the frustum cone. This line is used as center axis of helix when the helical tool path creating. The tool forms the sheet metal by following the helical path. Thus, tool movements do not damage the surface quality of the part. The helical tool path is shown on Fig. 3.

Table. 1 Chemical composition of DC01 steel (weight %).

C %	0,025
P %	0,009
S %	0,007
Si %	0,003
Al	%0,032

Table. 2 Mechanical properties of DC01 steel.

Yield Strength (MPA)	240.3
Tensile Strength (MPa)	336.4
% Elongation	35

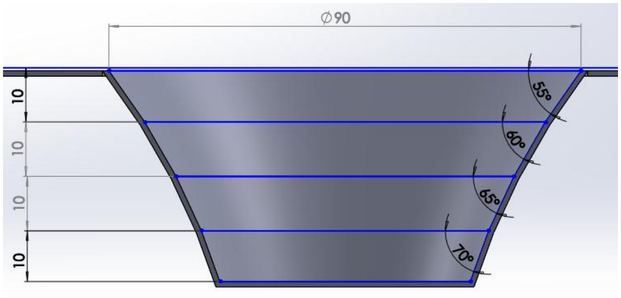

Fig 1. The dimensions of forming part.

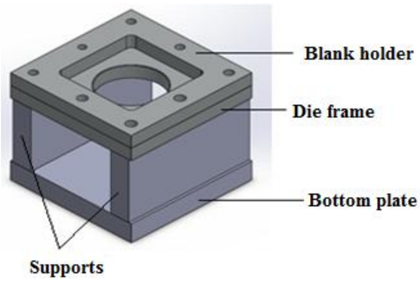

Fig 2. Assembly of support.

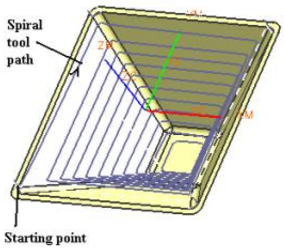

Fig 3. Helical tool path.

The ISF tool was chosen Ø10mm, spherical. Spindle speed, feed rate, step size was determined as 250 RPM, 500mm/min, 0,5mm, respectively. Tool coating and lubricant were used as test parameters. Four different types of tool were used in the experiments that are uncoated, titanium nitride (TiN), titanium aluminum nitride (TiAlN) and chromium carbonitride (CrCN) coated tools. These coating types are commonly used in deep drawing and spinning tools. As the lubricant, boron oil, water soluble drawing oil and forming and drawing oil were used. Boron oil is used chip removal operations like turning, milling, drilling, etc. Water soluble drawing oil is a special working fluid contains additives and miscible with water and has high lubrication properties and used for difficult operations like deep drawing. Forming and drawing oil contains exclusive lubricants, additives and corrosion preventive chemicals. The experimental plan is given in Table 3. STL files of forming parts were obtained by 3D laser scanning operation for creating CAD data of parts that were used for measuring the geometric accuracy of parts and the thickness of the formed sheet metal.

Table 3. Experimental parameters.

Sample Number	Coating	Lubricant
S1	Uncoated	Boron oil
S2	CrCN	Boron oil
S3	TiN	Boron oil
S4	TiAlN	Boron oil
S5	Uncoated	Water soluble drawing oil
S6	CrCN	Water soluble drawing oil
S7	TiN	Water soluble drawing oil
S8	TiAlN	Water soluble drawing oil
S9	Uncoated	Forming and drawing oil
S10	CrCN	Forming and drawing oil
S11	TiN	Forming and drawing oil
S12	TiAlN	Forming and drawing oil

III. EXPERIMENTAL RESULTS

The defect free parts were formed by ISF. CAD data of forming samples were generated from STL files and CAD data of samples was used for measurements. All samples were sectioned on XZ planes. Therefore, a section view of parts was used to investigate thinning, geometric and dimensional accuracy.

The maximum thinning was observed on S1 that was formed by uncoated tool with boron oil and the minimum was on the S9 formed by uncoated tool with forming and drawing oil. The thinning results of formed parts compared according to lubricant are given in Fig. 4, 5, and 6.

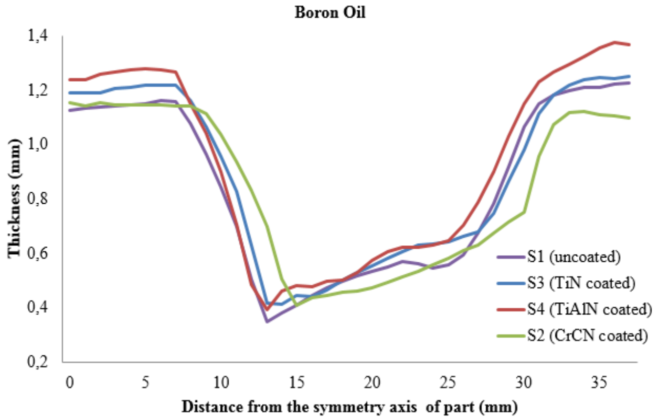

Fig 4. The effects of tool aspects on thinning of sheet formed by boron oil.

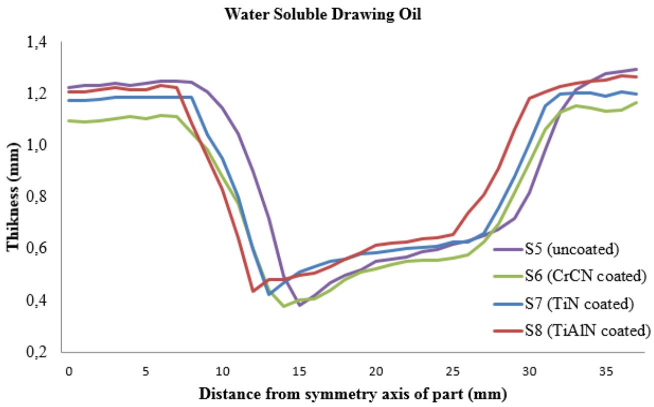

Fig 5. The effects of tool aspects on thinning of sheet formed with water soluble drawing oil.

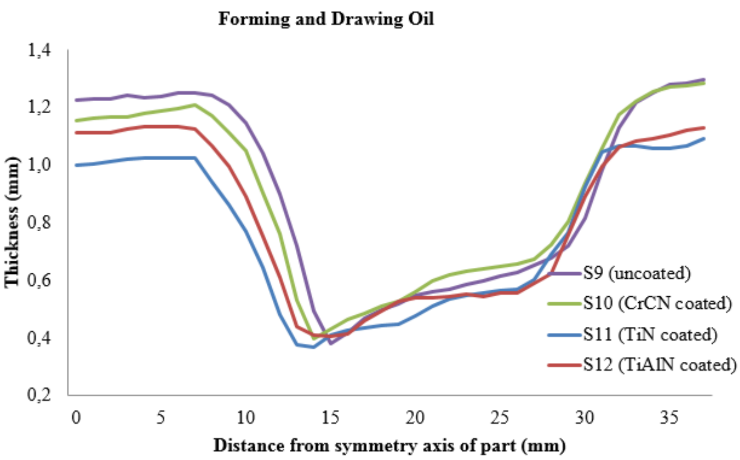

Fig 6. The effects of tool aspects on thinning of sheet formed by forming and drawing oil.

As seen in figures, the best results were obtained on samples that formed by forming and drawing oil. The maximum thinning was measured as 0,3667mm on S11 formed by TiN coated tool and the minimum was measured as 0,3993mm and 0,4099mm on both S10 formed by the CrCN coated tool and S12 formed by TiAlN coated tool.

The depth of forming part is one of the basic features could be used for searching the geometric accuracy. The measurement results are shown on Fig. 7, 8 and 9. The best results according to form depth were achieved on samples which were formed with the forming and drawing oil. In this study, it is observed that this lubricant was given better results with the CrCN coated forming tool, as seen on the S10.

When the geometric accuracy of forming parts with water soluble drawing oil examined, it is clearly seen that the sample has the closest form to target geometry is S5 formed by uncoated forming tool. On the other hand, S2 has the best form in sample group which were formed by boron oil.

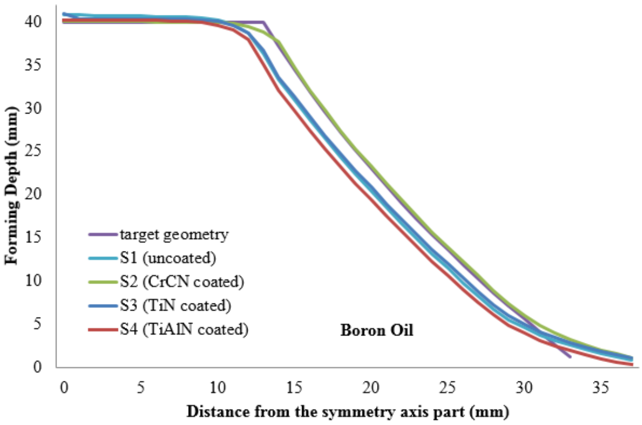

Fig 7. The effects of tool aspects on geometric accuracy of parts formed with boron oil.

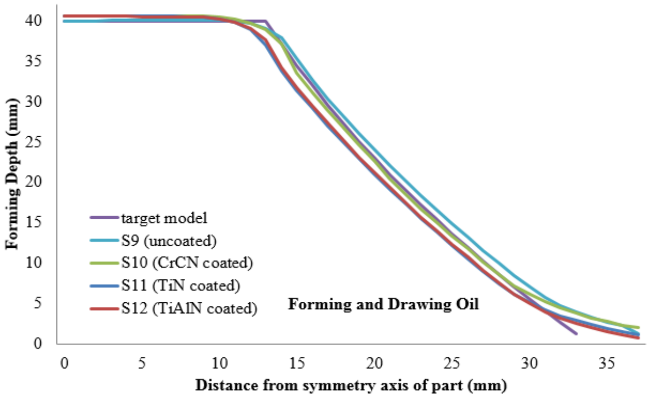

Fig 8. The effects of tool aspects on geometric accuracy of parts formed with forming drawing oil.

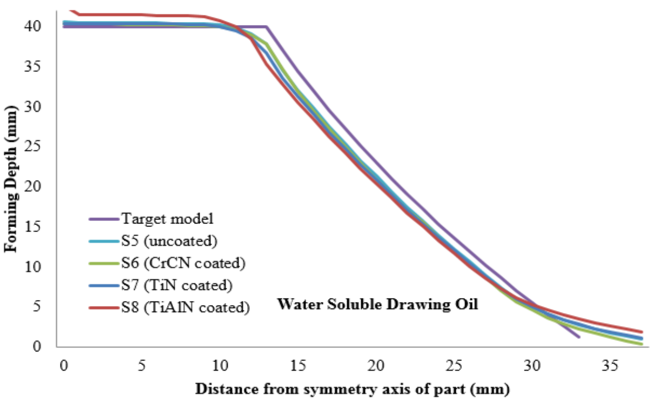

Fig 9. The effects of tool aspects on

geometric accuracy of parts formed with water soluble drawing oil.

IV. CONCLUSION

According to the above reported results it is possible to draw the following conclusions:

- The defect free parts were formed by Negative ISF.
- The maximum and minimum thinning were observed on sample which were formed with uncoated tools.
- Using forming and drawing oil is an advantage when samples are incremental formed by uncoated tool.
- CrCN coated tool has the minimum friction coefficient (about 0,2-0,3) gives the best result in both thinning and geometric accuracy is used with the forming and drawing oil which has the maximum viscosity according to other lubricants used in experiments.
- The quality of samples formed with boron oil was on a level with the samples formed with forming and drawing oil. Therefore, choosing the tool has the minimum friction coefficient on ISF operations gives better results when the lubrication of the deformation area is good.
- It is concluded that the cooling performans of water soluble drawing oil is better than the lubrication when the samples formed with water soluble drawing oil. The sample geometry which was given the best result observed on samples formed by uncoated tool in sample group formed with water soluble oil could not reached the target geometry.

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