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Research Article

Investigation of the Effects of Different Process Parameters on Deep Drawing Performance

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Abstract **–** Deep drawing is one of the most widely used plastic forming processes for obtaining three-dimensional deep structures from flat sheet metal. It is particularly important in the manufacture of cylindrical containers. When the depth of the part is greater than its diameter, the process is called "deep drawing" and can be successfully applied to various metal materials such as aluminium and steel.
In this study, deep drawing was applied to Erd 6224 steel sheets using a 250-ton hydraulic press. The sheet samples were subjected to processing under different lubricants and descent speeds in order to study the effect of these parameters on the deep drawing performance. The analyses evaluated the mechanical properties of the sheet materials, such as total elongation and thinning rates, under different lubricants and descent speeds. The results showed that the most uniform wall thickness was obtained using the Renol Ep/Msx deep drawing lubricant.

Keywords – Deep Drawing, Erd 6224 Steel Sheet, Thinning Ratio.

I. INTRODUCTION

Deep drawing is a plastic forming process in which sheet metal is placed in a specific mould and a press is used to achieve the desired three-dimensional shape [1]. The process is widely used, particularly in the automotive, aerospace and white goods industries [2]. The deep drawing process can produce containers, cylindrical or complex shapes by pushing the sheet material into the mould. Due to the ability of the sheet material to deform while maintaining its thickness, it is possible to produce lightweight, durable and aesthetically pleasing products. Factors such as the type of material used, mould design, lubricants and press speed have a significant impact on the quality of the final product. Optimising these parameters minimises defects such as wrinkles, cracks and thinning that can occur during the process. The correct choice of material and the correct setting of the process parameters are essential to the success of the deep drawing process.
Sheet metal forming is a technique commonly used in shaping metal materials. With this method, materials are formed into the desired shape through cutting or forming processes. One of the most preferred shaping techniques in the industry is the deep drawing method. The deep drawing process is used to obtain seamless containers or boxes with different geometric shapes from flat sheet materials. The drawing process is divided into shallow drawing and deep drawing, depending on the height of the part to be obtained. While shallow drawing can yield results in a single stage, the deep drawing process often requires multiple stages. In this respect, the deep drawing process holds significant importance in metal

forming processes [3]. Various special forming methods have been developed for shaping sheet metal parts with complex geometries. One of these methods is the hydromechanical deep drawing method [4–8]. The hydromechanical deep drawing method is a hydraulic forming method consisting of a combination of classical and liquid pressure forming processes. Karaağaç and Özdemir (2013) experimentally investigated the feasibility of shaping square geometries, which were shaped by a large number of forming operations using the classical molding method, in a single operation using the hydromechanical deep drawing method. For this purpose, they conducted experimental studies based on parameters that could be effective in shaping using a square geometry mold and punches in the hydromechanical deep drawing experimental setup, which was designed, produced, and calibrated. As a result of the experimental studies, by using the hydromechanical deep drawing method, Bakır and Erdemir achieved a drawing ratio of 2.6 in a single operation for the 6112 steel material. They also found that the shaped products exhibited a more homogeneous thickness distribution compared to the classical deep drawing method [9].
Zhao and colleagues (2024) conducted numerical simulations and experimental studies on the evolution of surface roughness and heterogeneous plastic deformation of micro deep-drawn (MDD) parts made from austenitic stainless steel foils at the grain scale. They stated that their finite element model showed higher accuracy in the localized stress and strain of the manufactured parts, fluctuation in thickness distribution, and evolution of surface roughness compared to the multiple stress-strain response model. The results indicate that coarse-grained foils correspond to intense strain localization, which is the main cause of surface roughening. The results also demonstrate a strong correlation between the magnitude of the Schmid factor and the ease of deformation. Additionally, they found that changes in the Schmid factor in different directions caused variations in deformation accumulation, which in turn affected the thickness distribution along the radial direction and the distribution of ears and wrinkles along the circumferential direction of the produced micro parts [10].

In this study, the effects of various parameters on the deep drawing performance of Erd 6224 steel sheet materials have been examined in detail. First, the press descending speed has been considered as an important parameter. This speed has been categorized to be 20%, 50%, and 100% of the press's maximum capacity, respectively. Another significant variable in the study is the types of lubricants used. In the experiments, both solid and liquid lubricants' performances were compared on sheet materials of the same thickness, observing different amounts of elongation and thinning ratios. Thus, the effects of different press speeds and lubricant types on the deep drawing process have been evaluated.

II. MATERIAL AND METHOD

In this study, Erd 6224 quality steel with a diameter of 370 mm and a thickness of 3 mm has been chosen as the sheet material used in the deep drawing processes. This material is a type of steel known for its high strength and formability characteristics in industrial applications. To avoid any problems during the deep drawing process and to ensure that the operation can be carried out efficiently, the surfaces of the sheet materials have been meticulously cleaned. Accumulated dirt, rust, and foreign substances on the surface can lead to deformation or material defects during the deep drawing process; therefore, the materials have been purified of such contaminants. The chemical composition of the sheet is also a factor that directly affects forming performance. The chemical composition of the experimental material is provided in Table 1.

Table 1. Chemical composition of Erd 6224 quality steel (%).

Experimental Material	Chemical Composition (%)				
Erd 6224 steel	C	Mn	P	S	Fe
	0.07	0.35	0.025	0.025	The rest

The deep drawing operations of the sheet materials were conducted at the factory belonging to Sampa Automotive Industry and Trade Inc., located in Samsun, within the scope of this study. These activities, integrated into the production process at the factory, were carried out under industrial conditions, thus yielding results that are applicable both academically and practically. Two different lubricants were used in the deep drawing processes: Presspate Sem 95/800 T as a solid lubricant and Renol Ep/Msx as a liquid lubricant. These lubricants help reduce the surface friction of the sheet metal, facilitating the smooth execution of the operation. Each lubricant was subjected to experiments at three different press descending speeds (20%, 50%, and 100% of the maximum speed of the press). Through this method, it was possible to systematically compare how different lubricants and press speeds affected the deep drawing process. The details of the experimental studies and the parameters used are provided in Table 2.

Table 2. Deep drawing test parameters.

Experimental Material	Lubricant Type	Press Descent Speed (According to maximum press speed)
Erd 6224	Liquid (Renol Ep/Msx)	20%
		50%
		100%
	Solid (Presspate Sem 95/800 T)	20%
		50%
		100%

III.RESULT AND DISCUSSION

As a result of the experimental studies, significant findings have been obtained regarding the deep drawing process under different processing parameters. The sheet material used during the process is 3.5 mm thick, and the same material with consistent properties was preferred for all experiments. The male die pressure value was set at 150 bar. Critical measurements such as the final thickness of the manufactured parts, thinning ratios, and percentage elongation were conducted. For example, in the experiment where the descent speed was set at 50%, the total length was measured at 127.55 mm, and thickness variations were observed in different regions of the product. The thickness values recorded were 2.78 mm, 2.90 mm, and 3.40 mm for the upper, middle, and lower sections, respectively. Figure 1 illustrates the overall appearance and cross-sectional structure of the produced product.

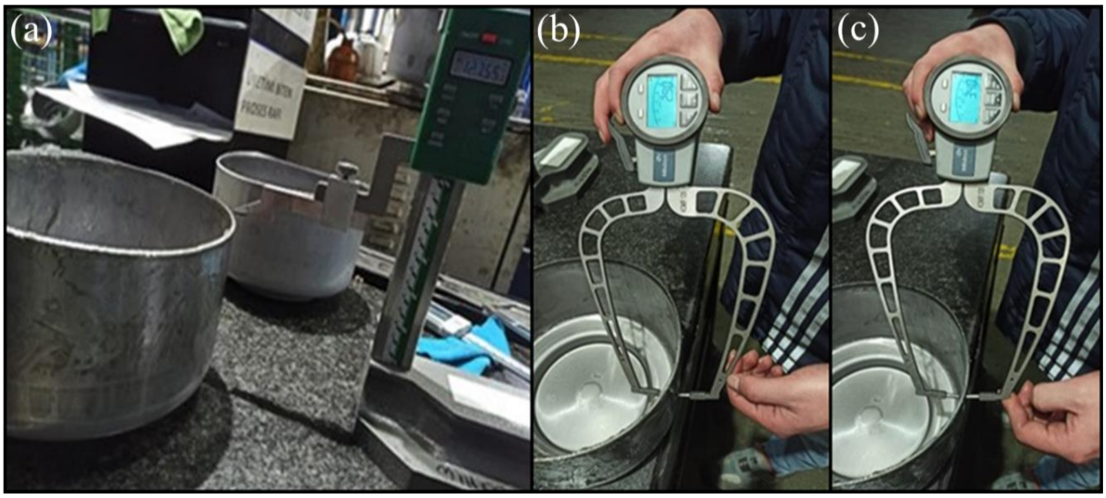

Fig. 1. (a) Sample obtained after deep drawing, (b,c) Measurement of material thickness at the middle and lower sections.

The results obtained from the experiment conducted with the solid lubricant Presspate Sem 95/800 T and a press descent speed of 100% have provided significant data regarding the geometry and thickness distribution of the product. The total length was measured to be 128.77 mm, and the thickness variation in different regions of the product was carefully examined. Thickness values of 2.46 mm, 2.62 mm, and 3.09 mm were detected in the upper, middle, and lower sections of the product, respectively. This thickness distribution illustrates how the sheet material was shaped under hydraulic press and the effect of the lubricant on thickness uniformity. Notably, the higher thickness value in the lower section indicates that the material experienced less thinning in this region and likely underwent greater stress. In contrast, the lower thickness values measured in the middle and upper sections suggest that the tensile stress and material flow were more balanced in these areas.

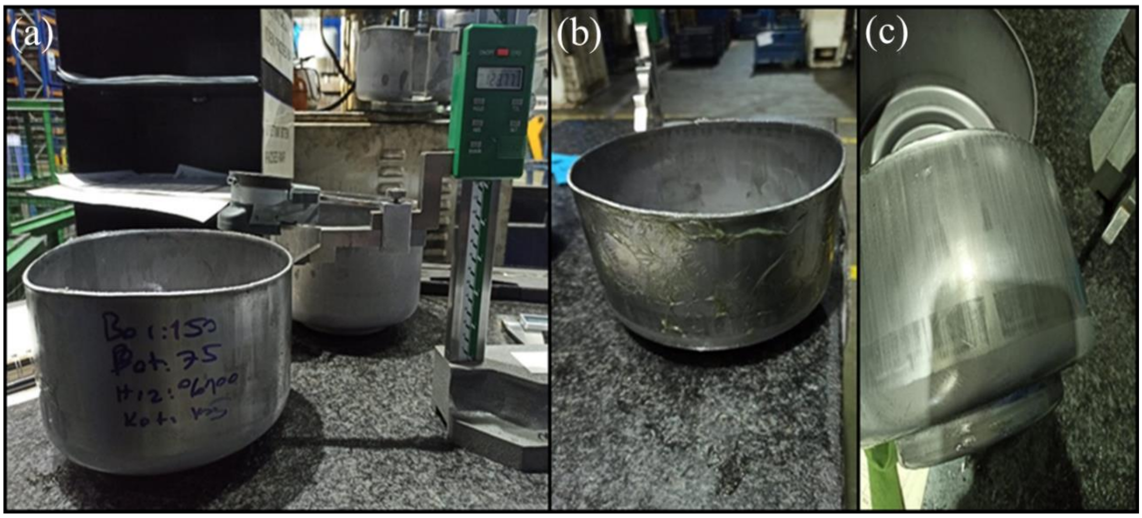

Fig. 2. Sample using solid lubricant at 100% press descent speed.

In Table 3, the geometry changes of the samples obtained as a result of the deep drawing processes are detailed, using different press descent speeds and lubricant types. In this process, the effect of each parameter used on the final dimensions and shape characteristics of the samples has been evaluated. The deformation and thickness changes caused by the different press descent speeds (low, medium, and high) and the solid and liquid lubricants applied in the experiments have been carefully measured and reported. Table 3 presents these data collectively, providing a comparative perspective on the effects of the parameters on the sample geometry.

Table 3. Deep drawing experiment results.

Exp. No	Press Descend Speed (%)	Lubricant Type	Initial Thickness (mm)	Final Thickness (mm) *Thinning (%)*			Final Length (mm)
				Üst	Orta	Alt	
1	100	Solid Lubricant	3.5	2.46 *%29.71*	2.62 *%25.14*	3.09 *%11.71*	128.77
2	50	Solid Lubricant	3.5	2.78 *%20.57*	2.90 *%17.14*	3.40 *%2.86*	127.55
3	20	Solid Lubricant	3.5	2.52 *%28*	2.66 *%24*	3.10 *%11.43*	127.17
4	100	Liquid Lubricant	3.5	2.56 *%26.86*	2.64 *%24.57*	3.30 *%5.71*	127.55
5	50	Liquid Lubricant	3.5	2.50 *%28.57*	2.70 *%22.85*	3.06 *%12.57*	126.99
6	20	Liquid Lubricant	3.5	2.62 *%25.14*	2.70 *%22.85*	3.06 *%12.57*	127.34

When evaluating the results in Table 3, it was observed that the samples exhibited less thinning in the lower sections, while more pronounced plastic deformation was noted in the upper sections. Particularly in the experiments where the press descent speed was set at 20% and a liquid lubricant was used, the thinning rates in the upper and lower sections of the samples were quite similar, indicating a more balanced deformation. In contrast, the highest total elongation rate was achieved in the experiments where the press descent speed was 100% and a solid lubricant was utilized. These findings reveal that the press speed and the type of lubricant have a significant impact on the mechanical performance of the material during the deep drawing process.

IV.CONCLUSION

In this study, the effects of different press descent speeds and lubricant types on the deep drawing process of ERD 6224 quality sheet materials conducted in a 250-ton capacity hydraulic press were investigated. The changes in parameters such as the thinning rate of the sheet and elongation were particularly analyzed in relation to these factors. Maintaining uniform wall thickness and achieving maximum elongation during the deep drawing process are critical for part quality and production efficiency. This process especially increases the need for controlled shaping and material distribution when producing parts with complex geometries.

Upon reviewing the results, it was observed that the most successful outcomes in terms of surface quality were achieved in experiments where solid lubricants were used. Specifically, the processes performed with Presspate Sem 95/800 T solid lubricant provided a smoother and more homogeneous quality on the material surface. In contrast, it was determined that the most effective lubricant for achieving uniform wall thickness was the liquid lubricant Renol Ep/Msx. While both lubricants offer different advantages, it has been understood that process parameters (such as press descent speed and lubricant type) need to be separately optimized to achieve specific objectives (uniform thickness or maximum elongation). This indicates that process parameters should be carefully selected based on material properties and final product requirements.

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