Frictional behaviour of DP steel in sheet metal forming at Various temperatures

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Abstract. The Dual Phase steel can be found in a wide range of sectors, including the nuclear and pharmaceutical ones. Sheet metal forming is a highly prevalent production technique. Conversely, there has been a lack of understanding about the sheet metal forming of DP steel, especially with regard to friction, a crucial parameter to comprehend sheet metal forming precisely. In this work, the frictional properties of DP steel have been discovered to interface experimentally with Inconel 718, the most widely used superalloy for sheet metal forming products. 2 mm thick material was used in the investigation, and its effects were examined under various conditions including load and different angles.

1 Introduction

New and precise manufacturing techniques are becoming more and more necessary. One technique that can yield precise and economical products is sheet metal forming. to create a particular manufacturing process using a particular material for a various purpose. It is a crucial stage in learning about the production process for the particular material. It's critical to comprehend the fractional interactions that take place during the forming process in order to make the products effectively.

The mechanical qualities of ASS 316L, which is a member of the various groups, are well recognized [1]. Additionally, its ductility and resistance to corrosion are strong qualities. [2,3]. According to numerous studies, this substance is utilized in the nuclear sector [4], in the transportation and storage of LPG [5], and in many other applications. One crucial factor in sheet metal formation is friction. It hasn't been thoroughly investigated or used for the examination of the metal forming process. The SMF process has been analysed using Coulomb's Frictional analysis; however, it has been discovered that this model is inaccurate and not taken into account the influence of crucial parameters like contact characteristics, such as punch speed, the angle at which the sheet deforms. On the other hand, it is

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exceedingly difficult to analyse and forecast the spring-back behaviour of the blank during the metal forming process using the most recent mol.

It is said that one essential factor that might regulate the dynamics of the production process in sheet metal forming activities is friction. It is well known that lubrication types and surface properties between the areas in contact between the die and blank [6]. Sincere efforts have been made recently to develop a model that can be utilised in a FEA code for simulations requiring as few assumptions as possible as well as an accurate and trustworthy technique to determine the impacts of friction in sheet metal forming [7-9]. The development of theoretical and experimental techniques to comprehend friction in SMF has a lengthy history.

A few of these include the Bay-Weinheim model [11], Amon ton-Coulomb's friction laws [10], and numerically developed models to know the frictional effects [12–14].

We have created our own friction measuring devices through custom design and construction in our current work. Furthermore, these investigations were conducted under diverse loading circumstances to provide insight into this on the sheet interface. This investigation aids in our comprehension of the impact of deformation speed. Experiments were then carried out on a 500 mm long ,30 mm wide and 2 mm thick DP steel strip . The equipment's provisions are then used to adjust this at various angles so that the effect on friction can be examined.

2 Experimental Details

2.1. Materials and methods

The DP steel samples were used for the friction testing. These specimens are prepared on a 2 mm thick cold-rolled sheet using a wire cut EDM machine. In relation to the rolling direction, these specimens are cut in three directions: perpendicular (90), diagonal (45), and parallel (0).

(a) (b)

Fig. 1: Set of friction test samples with 150x30 mm size before and after testing

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2.2. Friction test

The friction testing apparatus that we built and had made by outside suppliers so that we could investigate the properties of friction and how it affects sheet metal forming. This device can be purchased as a floor model that includes a power pack that gives the gadget the electricity it needs to operate its measuring components, which include hydraulic cylinders and load cells.

Fig. 2: The experimental Set up for Friction Test

The arrangement shown above shows that the Sample is fixed between two movable clamps. One of which is cylinder-shaped and has the ability to be fixed at an angle relative to the one with the sheet clamped between them. This is offered in order to research how a material's friction properties are affected by the Capstan angle. The direction of the cylinder has been positioned at intervals of 15, ranging from 0 to 60, because these settings are where the friction parameters are most important. The pyrometer and dyna therm setup, which measures temperature with the aid of a laser light, were used to conduct the experiments at high temperatures. As shown in Figure 2 and Figure 3.

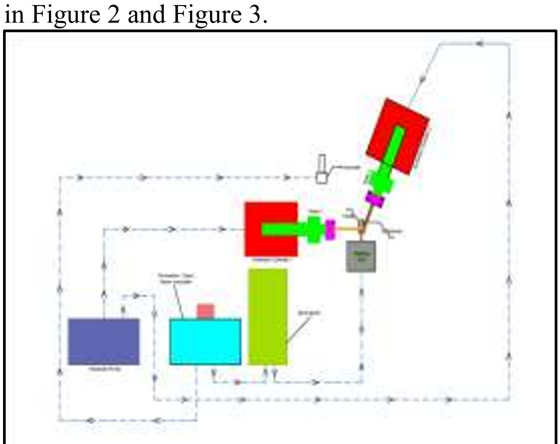


Fig. 3: Schematic view of friction testing device

3 Results and discussions

From table 1, it was observed that the friction was slightly affected by the bend angle. In addition, we observed that the friction value increased as the temperature grew, but the value ultimately depends on the lubricant we use in our test. There is presently Molycote and plastic used between DP steel sample and Inconel pin, and it has been seen that at 800°C with Molycote the friction value is 0.67, while plastic has a coefficient of friction of 0.71, where the lubricant values slightly vary the friction with respect to temperature.

Table 1:mechanical characteristics and DP590 steel's coefficient of friction under a 100 kg load and a 0° bent angle

S.No	**Temperature (^{0}C)**	**Orientation**	**UTS (Mpa)**	**YTS (Mpa)**	**n**	**Lubricant type**	**Coefficient of friction(μ)**
1	RT	0°,30°,60°,90°	966±31	758±21	0.174	- molykote plastic	0.51±0.09 0.31±0.02 0.38±0.09
2	500	0°,30°,60°,90°	477±21	319±15	0.113	- molykote plastic	0.82±0.12 0.44±0.06 0.52±0.05
3	700	0°,30°,60°,90°	177±9	149±12	0.089	- molykote plastic	0.91±0.09 0.62±0.07 0.61±0.03
4	800	0°,30°,60°,90°	121±11	89±10	0.093	- molykote plastic	0.96±0.03 0.67±0.05 0.71±0.04

At two distinct test conditions, the coefficient of friction (μ) is calculated using a range of lube. As the temperature rose, the μ value increased in each of the lubricant- and non-lubricant-filled cases, as shown in table 1. When contrasted with plastic, the lubricant molykote has a lower friction coefficient. With improved formability, the molykote lubricant is at 800°C.The samples with angles of 0° and 30° have lower friction values than the other specimens. It was also noted that the friction values in the cases made of plastic, molykote, and no lubricant rose by 45%, 36%, and 33%, respectively, as the temperature rose Shown in Figure 4.

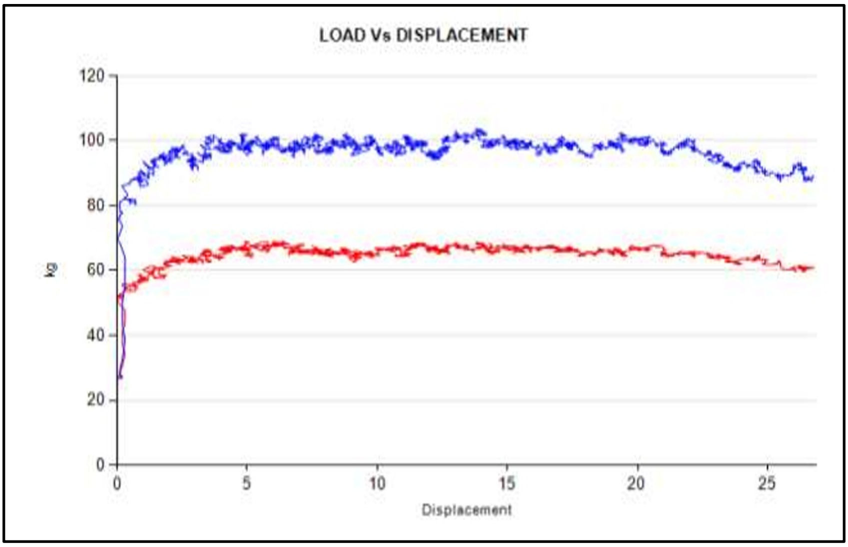
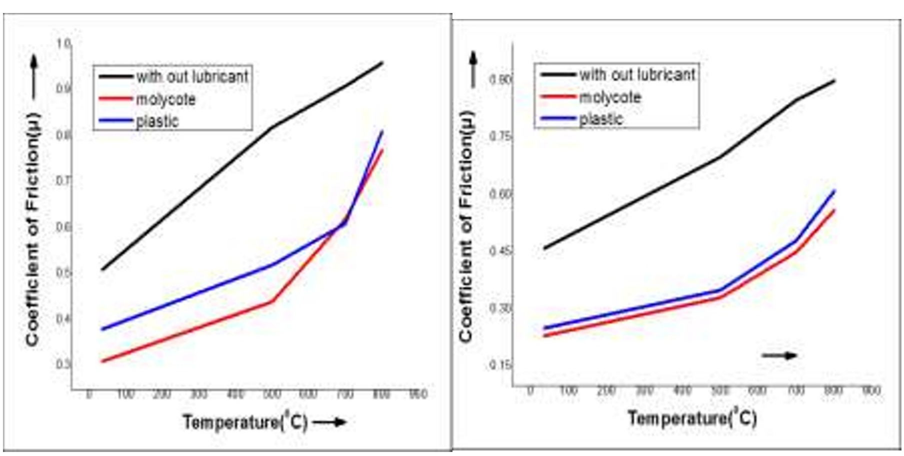
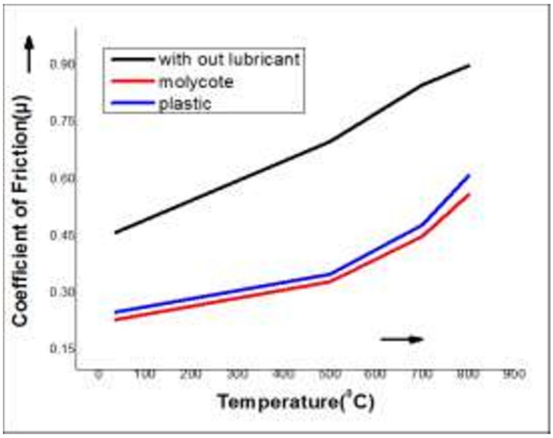


Fig. 4: Representation of Load vs Displacement graphs at (100 kg) with test angle 41.80

It was found that as the bend angle varied, the friction values also changed slightly. The average value served as the simulation's input for the FE code. Additionally, it was discovered that the friction value rose when the impacts of temperature were examined. However, the type of lubricant used will affect the friction levels. We applied Molykote between the pin and the job. Figure 5 illustrates how load decreases as temperature rises, and also displays how friction value varies with bend angle in relation to lubricant. The value for the coefficient of friction was measured using Molycote and found to be 0.51 at room temperature and 0.67 at 800°C. The material of a die also matters in addition to friction. In this case, we employ Inconel material for our dies. It was evident from Figure 5 that the molykote lubricant yields a smaller friction value ranging from nearly 15 to 25%, while in the case of plastic, it was 20 to 25%. Friction values were higher in the rolling side and at an angle of 67°.



(a) (b)



(c)

Fig. 5: Graph Shown Between μ vs Temperature at (100 kg) load, various lubricants and bend angles (a) 0^0(b)$41^0$and(c)67^0

4 Conclusions

The current study was to ascertain the DP steel sheet's frictional behaviour with regard to orientation at various load and test angles.

- Experimental observations have shown that the coefficient of friction rises as the weight and bend angle decrease.
- The values for the coefficient of friction were found to be 0.51 at room temperature and 0.67 at 800°C.
- The molykote lubricant yields a smaller friction value ranging from nearly 15 to 25%, while in the case of plastic, it was 20 to 25%. Friction values were higher in the rolling side and at an angle of 67°.

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