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Influence of Solid Lubricants on Formability of Commercially Pure Titanium and Steels

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Abstract: *The deformation behaviour of sheet metal is influenced by process parameters. Each process parameter will have its own effect on sheet metal stretching during Forming. In this study the Commercially Pure titanium and steels are selected for formability study using different solid lubricants, further optimal parameters contribution is analysed. It is evaluated that sheet thickness has maximum contribution on the formability of metals.*
Keywords: *Formability, solid lubricant, Taguchi technique, biomaterial*

I. Introduction

Titanium alloys are workhorse among other materials, used in aerospace industry due to their high specific strength, persistent corrosion resistance and excellent mechanical properties at elevated temperatures. This is due to excellent combination of properties such as high strength to weight ratio, high toughness, and good fatigue properties which make them attractive for many industrial applications [1]. Titanium and its alloys have been used as implant materials due to their very good mechanical and corrosion resistance and biocompatibility [1-4]. The most used biomaterial was commercially pure titanium (CP-Ti) [5, 6]. But their use is still limited due to high cost and advanced manufacturing techniques that are required to convert them into useful components. These high strength titanium alloys are less formable at room temperature and their formability is rather limited, often observed within a narrow thermo-mechanical processing window. The production of component at high temperature involves costly equipment and accordingly increases production cost and lead time. Thus suitable parameters are required to be selected at ambient temperature for maximizing formability of these advance metals. Formability is a measure of the ability of a sheet metal to be stamped or formed successfully into useful components without developing any failures [7]. Formability of a material is described by its flow curve, anisotropy (r) value, coefficient of hardening (n) value and forming limits diagrams [8]. The material with a high strain hardening exponent has better capacity for being formed [9]. The various parameters that influence deformation during forming are intrinsic property of material, lubrication conditions between die and material and strain bounding criteria.

1.1 Need For Formability Test

The basic forming characteristics of sheet metals are indicated to some extent even by the simple intrinsic mechanical properties obtained from tensile tests. A high strain hardening exponent is related to the ability of sheet material to undergo large uniform strains during biaxial stretching operations. Lower yield strength given lower spring back and facilitates shape attainment in lightly formed parts. A high value of the strain rate sensitivity index, also improves stretch ability by delaying the onset of localized necking. A high magnitude of anisotropy gives better draw ability in materials by resisting thinning. The major limitation of simple intrinsic properties, however, is that they completely ignore the effects of processing variables like die/punch geometry, lubrication, punch speed, sheet surface finish and tooling, on the forming behaviour of the sheet metal. Also, the tensile test does not simulate the Complex forming modes (strain states) existing in a real stamping. It is, therefore, essential to have tests that simulate the processing conditions and deformation modes existing during the industrial forming of sheet metal components. Such tests, called as Formability Tests, would allow better quantification of the formability of sheet metals, taking into account the synergistic interaction of sheet metal intrinsic properties and the processing conditions existing during processing operations. It is to be noted that most of the formability tests do not take into account the influence of the forming equipment itself. Further, no single formability test can describe the formability for all types of stamping applications. It is for this reason that various researchers have developed several formability tests. Formability of material is estimated by various methods, since the formability is influenced by various parameters, no single method gives satisfactory results some of the methods employed to estimate the formability reference are, i) Erichsen cupping test (IS-1756-1961) in which the depth of the formed cup without cracking or initiating of crack is a measure of formability ii)Olsen test iii) Swift cup test iv) Fukuri conical cup test v) Marciniak cup test vi)Forming limit diagrams/curves. As there are several methods to investigate formability with varying process parameters. Thus it becomes a necessary step to study the influence of these process parameters and their contribution using Taguchi optimizing technique.

1.2 Taguchi method

Taguchi method and ANOVA analysis is the best optimizing tool to quantify the percentage contribution of each parameters. Taguchi validated its basic philosophies of robust design by applying them in the development of many products [10] in many fields. A balanced comparison of levels of the process parameters and significant reduction in the total number of required experiments can both be achieved by using design of experiment. Taguchi method has been used to optimize flow-forming process for maximum deformation of the formed cups [11], to determine the influence of process parameter on drawability [12] of steel and aluminum alloys [13]. Taguchi Optimization technique has been beneficial in technology development and forming studies to design the experiments and to determine the influence of process parameters. The surface roughness of the flow-formed tube was predicted by using response surface methodology [14]. The influence of the diameters of perforations and ligament widths was studied on the forming limit strains [15]. Taguchi method has been used in forming studies for designing of experiments and analyzing the influence of process parameter on characteristics of formed parts [16-18]. It is a scientifically disciplined mechanism for evaluating and implementing improvements in products, processes, materials, and equipment [19]. ANOVA is a simple method with mathematical calculation and statistically based, objective decision-making tool for detecting any differences in average performance of groups of items tested [20]. It has been used in quantifying the influence of each factor and also which factor affects more. In this study, a statistical approach based on Taguchi and ANOVA analysis is adopted to determine the degree of importance of each of the process parameter on the formability of CP titanium, and steels.

II. Present Work

Fig 4 The materials investigated for their formability are mild steel, MS, stainless steel, SS 3O4 and CP Titanium, CP Ti, conforming to the compositions presented in table 1. The materials were tested as received conditions. Materials of 0.5 mm, 0.7mm and 1.0 mm sheet thickness are employed. Solid lubricants such as multipurpose grease, Grease MP and Poly tetra Fluoroethylene, PTFE are selected for the study. Modified Erichsen cupping test (Fig. 1) was employed in this study. The sheet metal is clamped between a retaining ring using a stud and bolt clamp. Blank holder force of 1000 Kgf is employed using torque wrench. The hemi-spherical penetrator is allowed to move forward till a crack is initiated on the cup (Fig. 2). The formability test was carried out as per Taguchi Design of Experiment.

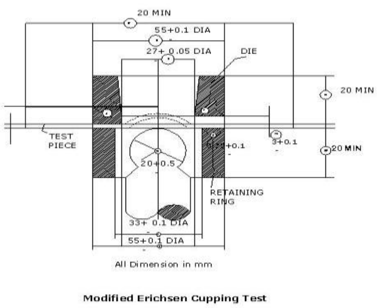

Fig. 1 Modified Erichsen Cupping Test

Fig. 2 MS samples after formability trest

Table1. Composition of materials

	Percentage of elements					
MS	C .059	Si 0.050	Mn 0.284	P 0.025	S 0.023	Cr 0.045
	Co 0.010	Cu 0.017	Ti 0.10	V 0.10	W 0.020	Pb 0.002
	Mo 0.010	Ni .010	Al 0.023	Sn 0.10	Fe 99.5	
SS 3O4	C 0.050	Si 0.55	Mn 1.68	P 0.039	S 0.010	Cr 18.216
	Co 0.182	Cu 0.486	Ti 0.010	V 0.057	W 0.037	Pb 0.011
	Mo 0.400	Ni 8.63	Al 0.010	Sn 0.016	Fe 69.658	
CP Ti	C 0.04	Mn 0.09	Al 0.09	Fe 0.14	Cr 0.02	Ti Bal

III. Results And Discussion

The process parameters with their level and Taguchi method orthogonal array (L9) is shown in Table 2 and 3.The S/N ratio calculated on the basis of quality control, big the better, is also presented in Table 3. Analysis of means is carried out to study the influence of different solid lubricant and other process parameters such as materials, sheet thickness during forming application. Qualitek 4 software is used to calculate S/N ratio and using the S/N ratio the main effects of each factor are determined. The main effects are shown in Fig.3.

Table 2 Parameters with their level

Factors	Level 1	Level 2	Level 3
Materials	MS	SS304	CP Ti
Sheet thickness	0.5	0.7	1.0
Solid lubricants	Dry	MP Grease	PTFE

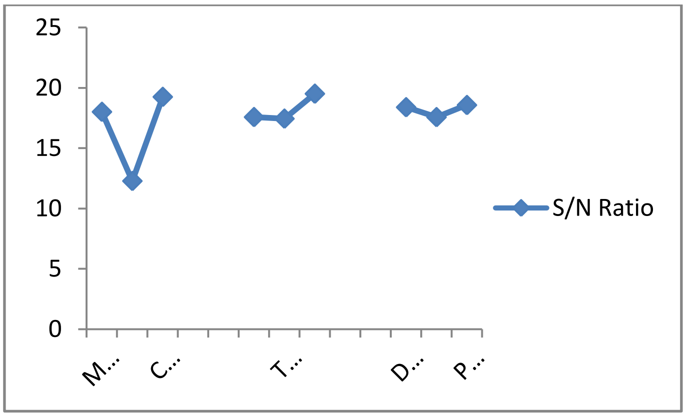

Fig 3 Main effects of process parameters

Table 3 L9 Orthogonal array and S/N ratio

No of trials	Parameters			
	Metals	Thickness of sheet metal	Solid lubricant	S/N Ratio
1	1	1	1	17.247
2	1	2	2	16.741
3	1	3	3	20.028
4	2	1	2	16.348
5	2	2	3	16.561
6	2	3	1	18.893
7	3	1	3	19.114
8	3	2	1	19.019
9	3	3	2	19.605

Fig. 3 shows that metals, CP titanium and MS have nearly same influence on S/N ratio and hence on formability, this can be attributed to the BCC structure of MS and influence of solid lubricant which played a vital role on formability Thus due to lubrication effect the material CP Ti also shows better formality (Fig. 3).

The ring shape fracture zone in deformation of material during forming or formability test is one of localized thinning, gives an indication of the position of the rupture during the test. Diameter of this ring shaped zone has a relationship between the Position for the rupture and the Erichsen cupping depth. Therefore it can be reasoned out that the radial gap between the fracture position and the axis of cup gives an indication about the effectiveness of the lubricant in obtaining higher Erichsen number values i.e., formability and helps in the selection of proper lubricants for the test as well as also during the practical forming process in the Forming industry. In a theoretical case with zero friction condition the fracture is expected to be positioned exactly over the centre of the cup. Fig 3 also shows that SS304 has thee least influence on S/N ratio, hence on formability.

ANOVA analysis is carried out using Qualitek-4 software to know the percentage contribution of each parameter on the formability. The percentage contribution obtained from ANOVA analysis is presented in Fig.4

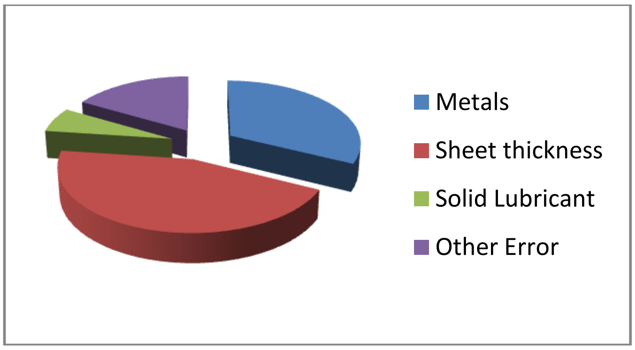

Fig. 4 Percentage contribution of each parameter

Fig.4 shows the percentage contribution of each parameter on S/N ratio. It is evident that Sheet thickness [21] has highest contribution in formability. The similar results were found by other researcher [22] that FLD0 increases while increasing thickness. Further, solid lubrication (Fig. 4) shows lesser percentage contribution among all parameters selected in the study.

IV. Conclusions

The formability of mild steel, SS 304 and CP Titanium has been investigated. The variables included i) Materials ii) dry friction and with solid lubrication. Two types of lubricants were employed (MP grease and PTFE) iii) Thickness of the sheets. The following observations are observed. i) Thicker sheets exhibited maximum contribution to formability iii) Solid lubricants such as PTFE and MP grease are having lesser contribution in comparison to other parameters selected in the study. Thus it is concluded that the thickness and selection of proper lubricant affects the formability.

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References

[1]. Z.-B. Cai, G.-A. Zhang, Y.-K. Zhu, M.-X. Shen, L.-P. Wang, and M.-H. Zhu, "Torsional fretting wear of a biomedical Ti6Al7Nb alloy for nitrogen ion implantation in bovine serum," Tribology International, vol. 59, pp. 312–320, 2013.

[2]. N. Masahashi, Y. Mizukoshi, S. Semboshi, K. Ohmura, and S. Hanada, "Photo-induced properties of anodic oxide films on Ti6Al4V," Thin Solid Films, vol. 520, no. 15, pp. 4956–4964, 2012.

[3]. J. Cheng, J. Yang, X. Zhang et al., "High temperature tribological behavior of a Ti-46Al-2Cr-2Nb intermetallics," Intermetallics, vol. 31, pp. 120–126, 2012.

[4]. L. Bolzoni, E. M. Ruiz-Navas, E. Neubauer, and E. Gordo, "Mechanical properties and microstructural evolution of vacuum hot-pressed titanium and Ti-6Al-7Nb alloy," Journal of the Mechanical Behavior of Biomedical Materials, vol. 9, pp. 91–99, 2012.

[5]. K. Ida, Y. Tani, S. Tsutsumi et al., "Clinical application of pure titanium crowns," Dental Materials Journal, vol. 4, no. 2, pp. 191–195, 1985.

[6]. B. Bergman, C. Bessing, G. Ericson, P. Lundquist, H. Nilson, and M. Andersson, "A 2-year follow-up study of titanium crowns," Acta Odontologica Scandinavica, vol. 48, no. 2, pp. 113–117, 1990.

[7]. AnoopkumarShukla, G Chandramohan Reddy et al , Experimental evolution of formability of sheet metals under PTFE lubricated conditions, Journal of institution of engineers (India), Vol 92, 2011 pp. 29-33.

[8]. D Banabic, HJ Bunge, K Pohlandt, A E Tekkaya, Formability of metallic material, Edited by D Banbic, Springers 2000, XV. Technical tidbit (publication by Materion Brush Performance Alloys 6070 Parkland Blvd. Mayfield Heights, OH 44124 (216) 486-4200 (216) 383-4005 Fax (800) 375-4205 Technical Service, issue no 51 , Mar 2013, pp. 1-2.

[9]. Technical tidbit (publication by Materion Brush Performance Alloys 6070 Parkland Blvd. Mayfield Heights, OH 44124 (216) 486-4200 (216) 383-4005 Fax (800) 375-4205 Technical Service, issue no 51 , Mar 2013, pp. 1-2.

[10]. Phadke, M.S, Quality Engineering Using Robust Design, Prentice Hall, (1989) NJ, US.
[11]. M.J.Davidson, K.Balasubramanian, and G.R.N.Tagore (2008), Experimental investigation on flow-forming of AA6061 alloy-A Taguchi approach, Journal of Materials Processing Technology, vol. 200, pp. 283-287.
[12]. R. Padmanabhan, M.C.Oliveira, J.L.Alves (2009), Analysis of a Deep drawing process using finite element simulations, Int J Mater Form, Vol. 2 .no.4, pp. 347–350.
[13]. G. Venkateswarulu, M.J. Davidson, and G.R.N. Tagore (2010), Influence of Process parameters on the cup drawing of Aluminum 7075 sheet, International Journal of engineering science and technology, vol. 2 (Issue 11) pp. 40-49.
[14]. Davidson M.J., Balasubramanian K. and Tagore G.R.N., 2008. Surface roughness prediction of flow-formed AA6061alloy by design of experiments, Journal of Materials Processing Technology, Vol. 202, No. 1-3, pp.
[15]. Elangovan K. and Sathiya Narayanan C., 2010. Application of Taguchi approach on investigation of formability for perforated Al 8011 sheets, International Journal of Engineering, Science and Technology, Vol. 2, No. 5, pp. 300-309.
[16]. G. Taguchi, S. Konishi, Taguchi method, orthogonal arrays and linear graphs, Tools for Quality Engineering, American Supplier Institute, 1987pp. 35–38.
[17]. X. Duan, T. Sheppard, Influence of forming parameters on the final subgrain size during hot rolling of aluminium alloys, J. Mater. Process.Technol. 130–131 (2002) 245–249.
[18]. M. Colgan, J. Monaghan, Deep drawing process: analysis and experiment, J. Mater. Process. Technol. 132 (2003) 35–41.
[19]. W.T. Cheng, H.C. Li and C.N. Huang "Simulation and optimization of silicon thermal CVD through CFD integrating Taguchi method" Chemical Engineering Journal, Volume 137, Issue 3, April 2008, Pp 603-613
[20]. Alfredo Lambiase, and Salvatore Miranda "Performance parameters optimization of a pneumatic programmable palletizer using Taguchi method", Robotics and Computer-Integrated Manufacturing, Volume 19, Issues 1-2, February-April 2003, Pag**es** 147-155.
[21]. JD Bressan Influence of thickness size in sheet metal DOI 10-1007/S12289-008-0030-3 Springer paris 2008.
[22]. R. J. Bhatt, Determination of Effects of Various Parameters on Forming Limit Diagram using FEA International Journal of Science and Research (IJSR), May 2013Volume 2 Issue 5,pp.101-103