SELECTION OF THE TOOL MATERIALS, LUBRICATIONS AND SELF-LUBRICATING COATINGS FOR THE ROTARY FORMING PROCESS OF NICKEL SUPERALLOYS SHEETS

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Abstract

The paper presents the results of research on the selection of tool materials, lubricants and self-lubricating coatings in the process of rotary forming of nickel superalloy Inconel type sheets. The abrasiveness tests of sheets were carried out with roller made of ceramics FRIALIT® F99.7 and steel CALDIE®. The discs were covered with single layers of lubrications: WD-40, Loctite 8023, Loctite 8151AS, Bonderite Aquadag18%. In parallel the discs were coated with a self-lubricating coatings: silver, zinc and copper. The properties of friction pairs were determined based on weight loss.The obtained samples were subjected to detailed research focused on the analysis of the quality of the surface after deformation. The test results are shown in tables, diagrams and surface profiles.

Keywords: Rotary forming, Inconel, abrasiveness, lubrication, roughness

1. INTRODUCION

Inconel Nickel superalloys are used in the aerospace industry, including the production of aircraft engines [1-2]. Made into axisymmetric cover elements of combustion chamber of jet engines in the rotary forming process [3-7]. In this process the change of shape and dimension of the sheet takes place by using a forming roll and stencil. Forming process is carried out in several operations. Each leads to the controlled thinning of the wall. Due to the specific properties of the Inconel nickel superalloy, the rotary forming process complicated [8-9]. Rotary forming these alloys generates a lot of disadvantages, among others: circumferential and radial cracking, surface cracking, sticking of material on the rollers and many others, which disqualify the final product. The separation of the shaped material surface and tools by the application of lubricants is essential in most forming processes and performs two key functions: separating and cooling. The separation of the two surfaces provides less friction, easier deformation and reduces the load on tools. Also it reduces tool wear by avoiding the sticking of material at the surface of the tool [10]. Increasingly, on the friction surfaces are used self-lubricating coatings, which significantly increase the wear resistance [11].

Presented in the paper research led to the selection of the optimal parameters of friction and lubrication in the rotary forming process of Inconel nickel superalloy by selection of materials for forming tools and lubricants which in turn will improve the surface quality of the product and significantly reduces tool wear.

1.1. Experimental setup

For the test were used discs with a diameter of 65 mm, made of Inconel® 625 alloy with a thickness of 1.2 mm. Sheet able to supply were examined in terms of surface roughness and profile using a profilometer Vecco NT930. Cut test discs were weighed on Sartorius CP225D. The results are a basis for abrasiveness test and for evaluation of surface quality after deformation. The scheme of the test is shown in **Figure 1**.

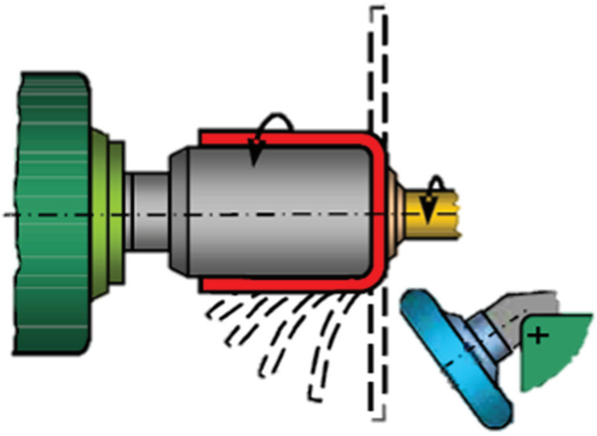

Figure 1 Scheme of the rotary forming process [12]

For the study was used laboratory stand FLW-1. To spindle was attached template in the shape of a truncated cone with an angle of inclination of 45^0. Shaping roll was placed in a saddle at an angle of 45^0. The speed of deformation amounted to 1,250 rev / min. In each test performed with eight roller pass. **Figure 2** presents test stand.

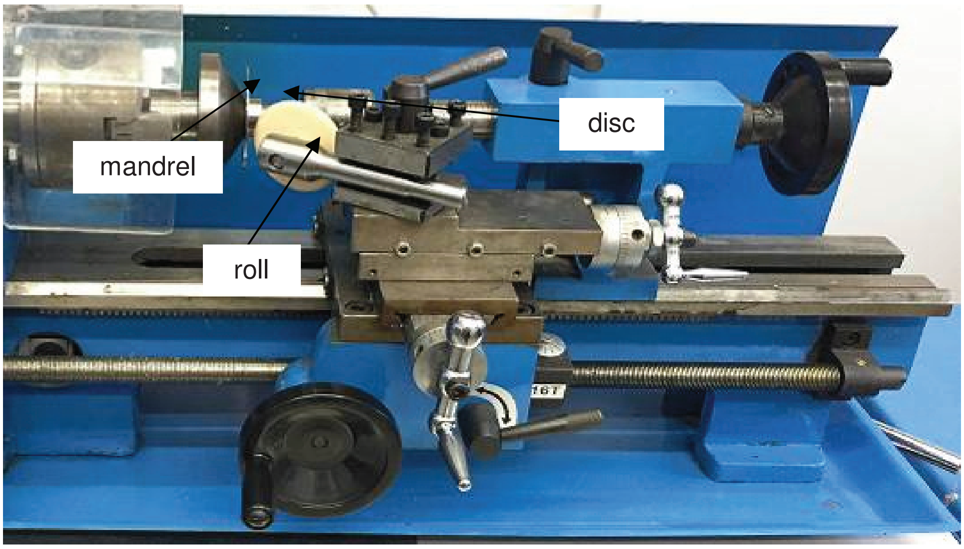

Figure 2 Test stand FLW-1

Laboratory tests included the production of axisymmetric metal products in the rotary forming process with the use of forming roll made of chrome-molybdenum-vanadium steel Caldie® alloy and ceramics FRIALIT® 99.7.

In the first stage discs were deformed without the use of lubricants and self-lubricating coatings. In the second stage discs were coated with a single layer of lubricant. Used lubricants were based on graphite and aluminum with different consistency. Four lubricants were selected for testing, WD-40, Laclite 8023, Loctite 8151AS and Bonderite Aquadag 18%. In the third stage discs were covered with three self-lubricating coatings. The coatings were applied on the discs by electrochemically method. The thickness of the layer was 2 to 30 microns. It was chosen three self-lubricating coatings: copper, silver and tin.

After each test the samples were cleaned using Intersonic ultrasonic cleaner. After each step, we performed a series of tests, which consisted of abrasion test for the loss in weight, roughness test and surface profile.

Roughness Tests were made according to norm [13]. The results of the study are presented in the form of tables, charts and measurements of the surface profile.

2. RESULTS

The results of surface roughness for the Inconel® 625 samples in initial conditions, with the lubricants and self-lubricating coatings are shown in **Figures 3 - 8**. The results are presented in the form of 3D profiles. For evaluating they were chosen the parameters of the most common and most often used to describe surface roughness such as arithmetic mean deviation of the roughness profile from the mean line (R_a) and the height of roughness (R_z). R_a is a key parameter for the evaluation of the surface roughness in metal forming.

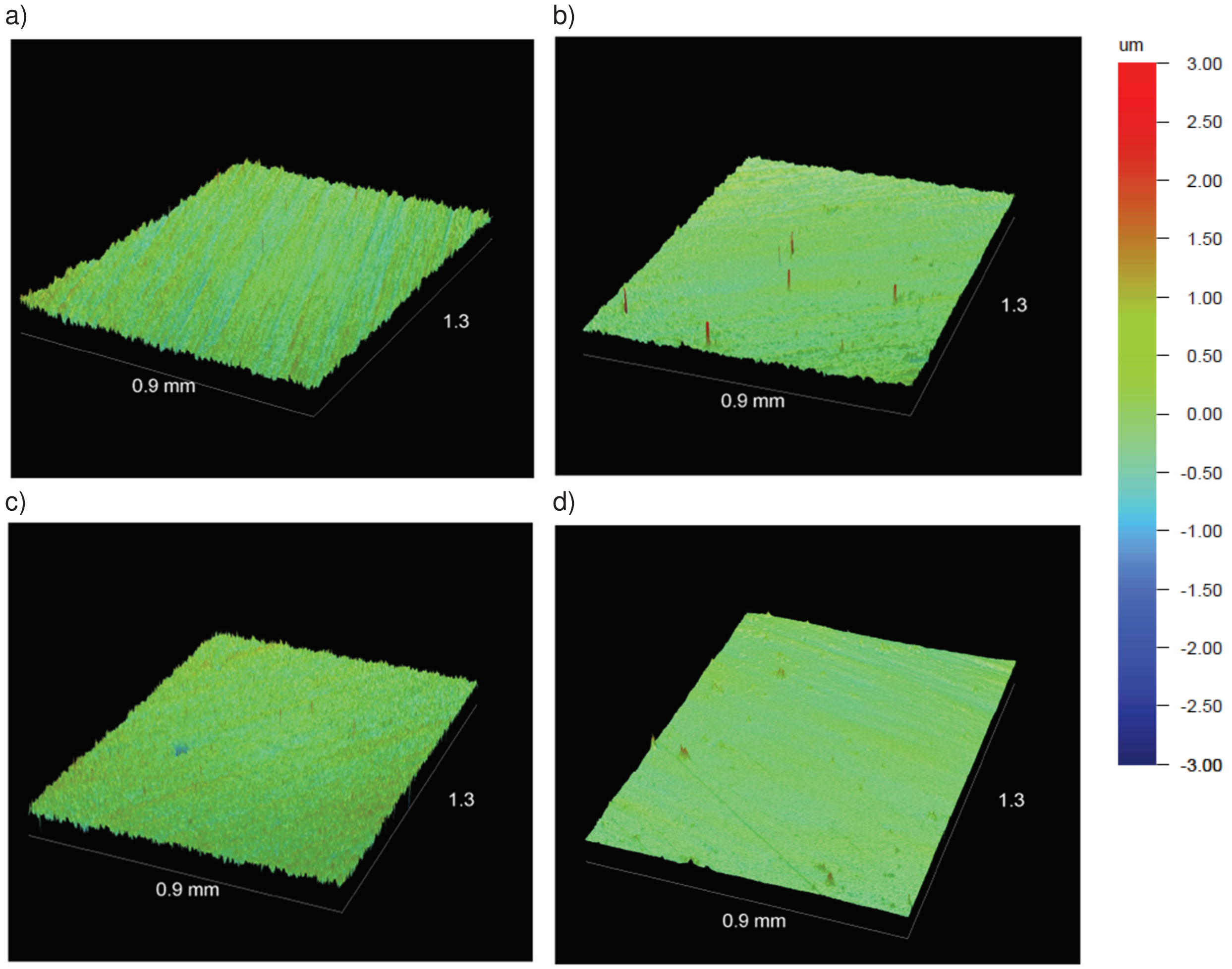

Figure 3 The results of surface roughness and surface profile of the Inconel® 625 befor defomation; a) without coating, b) with Sn coating, c) with Ag coating, d) with Cu coating

Surface samples of batch material Inconel® 625 is smooth, with an average roughness R_a = 206.67 nm and R_z = 3.48 μm. The sample surface coated with copper has an average roughness three times lower, R_a = 80.18 nm and R_z = 2.30 μm. The average roughness of the sample with a silver coating is similar to the roughness of the batch material sample.

Materials deformed by roll made of Caldie® have a lower weight loss at the level of 0.00018 g, than with use of ceramic roll for the Inconel® 625 where the abrasion is 0.00338 g. This was confirmed by the roughness tests. In the case of FRIALIT® 99.7 the surface is more uneven.

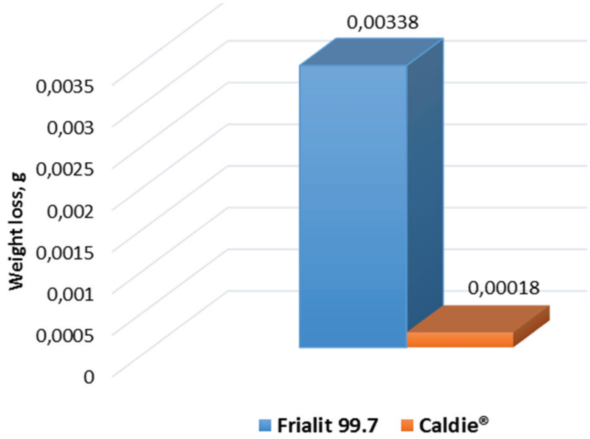

Figure 4 The results of abrasiveness made by analyzing the weight loss

a) b)

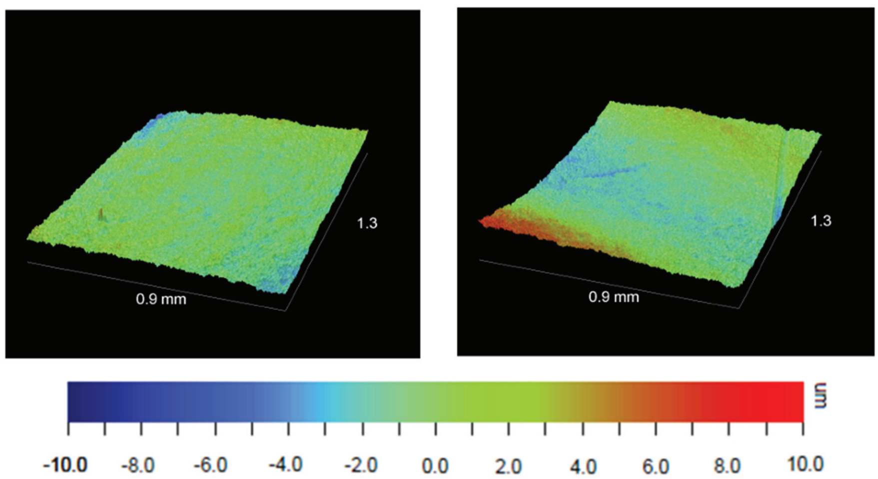

Figure 5 The results of surface roughness and surface profile of the Inconel® 625 after defomation;
a) Caldie® roll, b) FRIALIT® 99.7 roll

In a next step was tested the influence of the lubricant on the attrition of Inconel® 625 during deformation.

a) b)

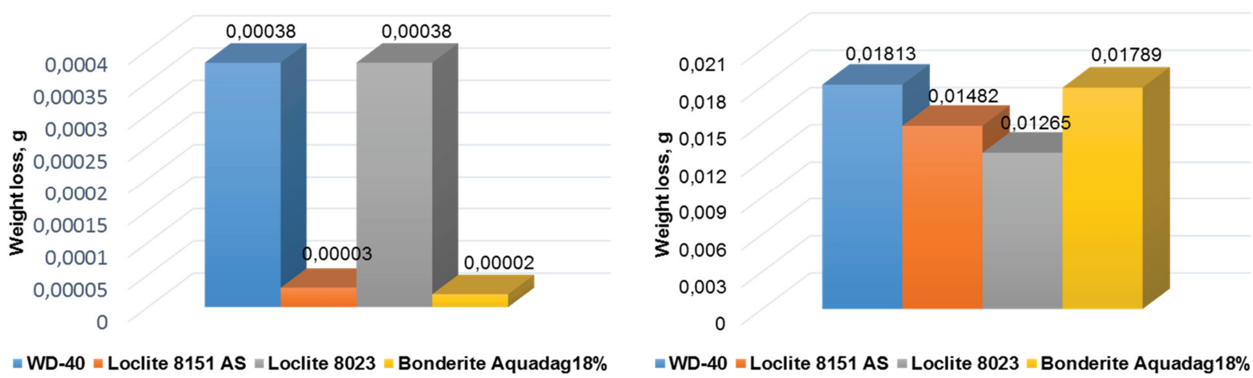

Figure 6 The influence of grease for attrition of Inconel® 625 during deformation;
a) Caldie® roll, b) FRIALIT® 99.7 roll

The smallest weight loss was observed for Caldie® roll and discs covered with grease Loctite 8151 AS and Bonderite Aquadag18%. In the case of roll made of FRIALIT® 99.7 the least weight loss was obtained while using Loctite 8,023. Use of the lubricants in the shaping of Inconel® 625 sheets using Caldie® roll allowed to six-fold reduction of disc weight loss, which reflects a very high surface quality of the product (**Figure 6**).

a) b) c)

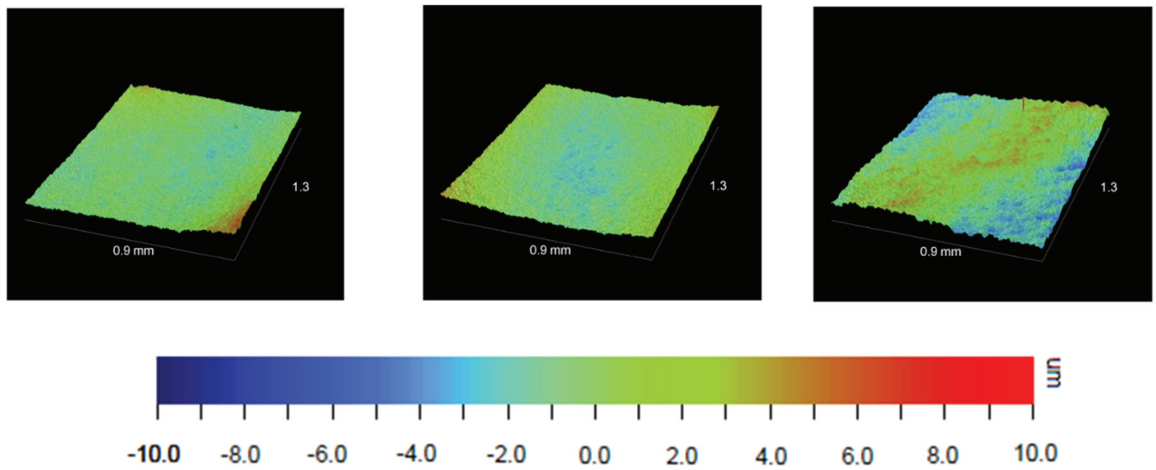

Figure 7 The results of surface roughness and surface profile of the Inconel® 625 after defomation with lubrications; a) Caldie® roll with Loctite 8151AS, b) Caldie® roll with Bonderite Aquadag18%, c) FRIALIT® 99.7 roll with Loctite 8023

In a next step, the effect of self-lubricating coatings on the abrasion of Inconel® 625 was tested during deformation. On the basis of previous results roll of FRIALIT® 99.7 was discarded. The smallest mass loss was obtained for the silver coating.

a) b)

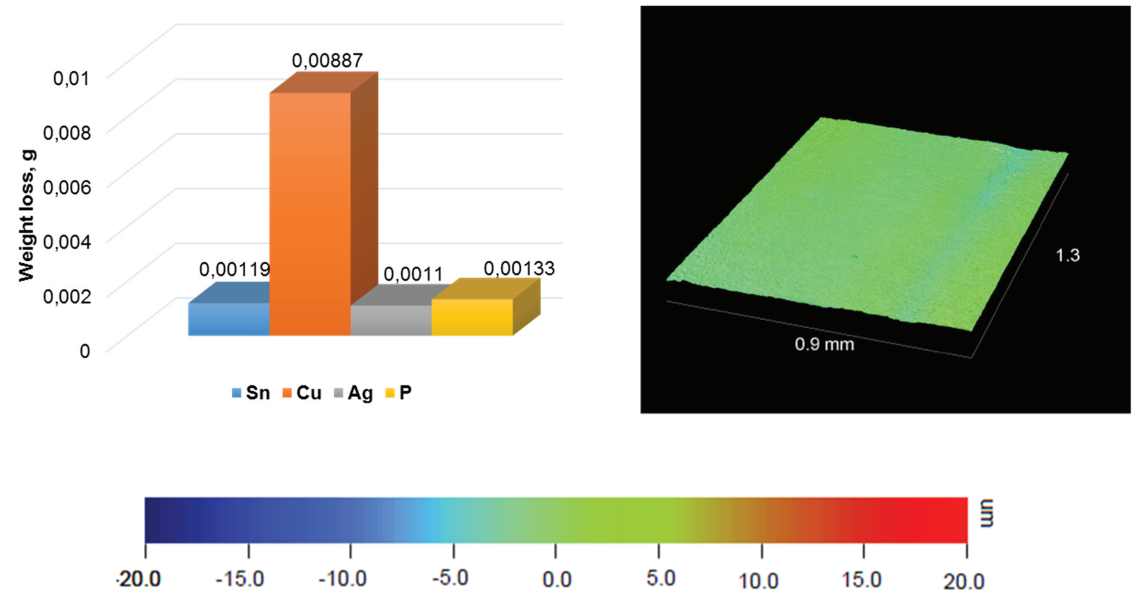

Figure 8 The influence of self-lubricating coatings on attrition of Inconel® 625 during deformation of Caldie® roll; a) summary chart of weight loss, b) surface roughness for silver coating

3. CONCLUSION

1) The proposed plan of research allowed to define the optimal conditions for rotary forming in the selection of lubrication and self-lubricant coating.
2) The results allowed us to select the best material for forming tools
3) The results enabled the selection of the best coatings and lubricants.
4) Results of usage based on weight loss, can not be a basis for assessing combinations used tool-material- coating / lubricant because of the minimal values.
5) The next step will involve research at increased temperature with additional agents to prevent carburization.

REFERENCES

[1] C.T. Sims M. N.S. Stoloff, W.C. Hagel, Superalloys II, Ed. J. Willey & Sons, New York, 1987,

[2] O. Music, J.M. Allwood, K. Kawai, A review of the mechanics of metal spinning, J. Mater. Process. Technol., 2009, vol. 210 (1), pp. 3-23,

[3] M. Runge, Spinning and flow forming, Leifeld GmbH Werkzeugmaschinenbau/Verlag Moderne Industrie AG, D-86895, Landsberg/Lech, 1994,

[4] C.L. Packham, Metal spinning and shear and flow forming, Sheet Metal Industries, 1997, pp. 326-329,

[5] K. Żaba, M. Nowosielski, S. Puchlerska, M. Kwiatkowski, P. Kita, m. Głodzik, K. Korfanty, D. Pociecha, T. Pieja, Investigation of the mechanical properties and microstructure of nickel superalloys processed in shear, Archives of Metallurgy and Materials, 2015, vol. 60(4), pp. 2637-2644,

[6] Quigley, J. Monaghan, Metal forming: an analysis of spinning proces, Journal of Materials Processing Technology, 2000, vol. 103, pp. 114-119,

[7] C.C. Wong, T.A. Dean, J. Lin, A review of spinning, shear forming and flow forming processes, International Journal of Machine Tools & Manufacture, 2003, vol. 43, pp. 1419-1435,

[8] Plewiński, T. Dregner, Spinning and flow forming hard-to-deform metal alloys, Archives of Civil and Mechanical Engineering, 2009, vol. 9, no.1, pp. 101-109,

[9] M. Kwiatkowski, K. Żaba, M. Nowosielski, D. Pociecha, T. Tokarski, P. Kita, Temperature measurement in the rotary forming process of a nickel superalloys (INCONEL) sheet during induction heating, Key Engineering Materials, 622-623, 823-830 (2014),

[10] N. Bay, Metal Forming and Lubrication, Encyclopedia of Materials: Science and Technology, no. 2, 2001, pp. 5377-5380,

[11] N. Espallargas, L. Vitoux, S. Armada, The wear and lubrication performance of liquid-solid self-lubricated coatings, Surf. Coat. Technol.,2013, vol. 235, pp. 342-353,

[12] M. Jurković Z. Jurković, M. Mahmić, an analysis and modelling of spinning process without wall-thickness reduction, METABK, 2006, vol. 45(4), pp. 307-312,

[13] PN-EN 10049:2008P