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Original article

Ironing process in conditions of constant and variable lateral force

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ABSTRACT

Comparison of application of constant and variable lateral force in strip ironing process with double side thinning are presented in the paper. Given are the experimental results for single and multiphase ironing process with constant lateral force during the course of particular process. Material used was mild steel DC04. Stripes were 20 mm wide and 2.5 mm thick. Constant lateral force intensities were 5, 10 and 15 kN. Lubrication was with appropriate mineral oil and grease.
In other side given is analysis of idea of possibility to apply variable lateral force during the strip ironing process and consequences of this action. Expected is control of strip thickness variation with difficulties because of contact and other appearances influence.

Key words: *ironing process, strip sliding test, variable lateral force;*

1. INTRODUCTION

Ironing forming process have great appliance in modern metal forming industry. He combine characteristics of sheet metal forming and bulk forming processes. One aspect of significance of ironing technology illustrate numerous published research papers. For this opportunity chosen are selected references [1-16].
Physical modeling have great importance in ironing process research. There are many approaches, but most of them are based on tribological experiments. Different simulative tests were been developed in order to obtain contact parameters, to evaluate the performance of the individual lubricants, material wear resistance etc. All the tests are simulating real process conditions and allow to determine important parameters. Widely is used so called Schlosser test [1]. One of the first studies about limitations and problems with this test is given in paper [2]. Different considerations are presented in next papers: friction and lubrication [3-5], manufacturing issues of particular part etc. [6].
In Faculty of Engineering (former well known Faculty of Mechanical Engineering for long years), University of Kragujevac, performed were extensive researches in the past decade based on tribological experimental modeling of ironing process [7-16]. Main physical model is double side thinning strip ironing test, but with new approaches presented in articles [7] and [16]. Different lubrication issues were investigated in papers [8-12]. An attempt with strip ironing test numeric simulation was made in [13]. Extended research with different materials, lubricants, strain rates etc. on classic model presented are in master thesis [14]. Influence of process parameters on the friction coefficient research is given in [15]. In [16] exposed was new method for friction coefficient and contact pressure determination depending on drawing force, lateral force, tool and sample geometry.
In this paper authors are exposed idea that is possible to realize variable strip thickness by acting of continuously variable lateral force in double side thinning ironing test.
Fig. 1 represents scheme of main test tooling elements acting. The thick metal strip is being gripped into holding jaw. The jaw with the sample is moving in vertical direction by acting of drawing force F. Lateral forces FS makes thinning of strip sample. Acting of two lateral forces and drawing force F simulate the industrial ironing tool work. There is important to notice that in clasical situation with constant intensity of lateral force FS during sliding

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process, exist need of initial indentation of lateral tool elements before start acting of drawing force F. Details of process parameters determination can be seen in [7, 11, 14, 16].

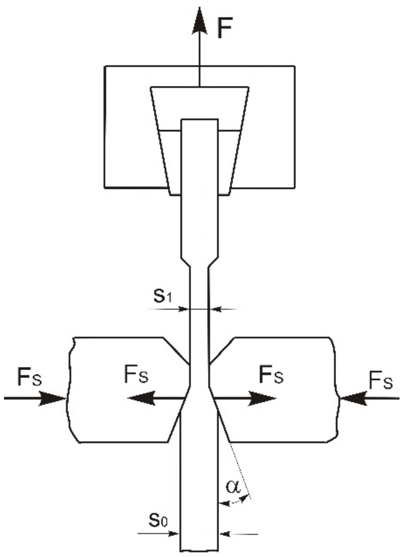

Fig.1 Acting of test tooling elements

2. THINNING WITH CONSTANT FORCE

Authors paid attention to deformation of thinning in this and next chapter. It is important to notice that here lateral force intensity is constant in course of single sliding process.

Drawing force F dependence on sliding length can be seen in Fig. 2. Strips were made of low carbon steel DC04. Sample width is 20 mm and initial thickness is 2,5 mm. Applied lubricant is mineral oil and sliding speed is 20 mm/min. With such a speed sliding process last about 3 min on 60 mm length. All the experiment details are given in [14]. There are 3 curves in Fig. 2. Each curve corresponds to appropriate lateral constant force FS, and relate to single strip sample. Constant intensity of FS make constant thinning deformation. For example, with FS=15 kN percentage thinning is 17% (thickness goes from 2.47 mm to 2.05 mm).

Fig. 3 shows other situation. Used was one sample and after first 60 mm of sliding pass, performed is second (approximately 45 mm), third (30 mm) and fourth (15 mm) repeatedly over the same surface. Lateral force intensity was 5 kN for all the four phases each. Realized thinning was relatively small, up to 2,4%.

Fig. 4 presentation is analogous to Fig. 2 with difference in applied lubricant which there is special MoS2 grease [14]. Course of sliding process lasting in condition of smaller friction, and drawing force curves position is lower than in Fig. 2. Thinning deformations are similar to Fig. 2 case.

Fig. 5 correspond to Fig. 3, but grease like lubricant make change in ironing sliding process. There are four passes also, like in Fig. 3 but drawing force is lower and lower in next passes each. This shows different process character in relation to Fig. 3. Thinning deformations are lower also.

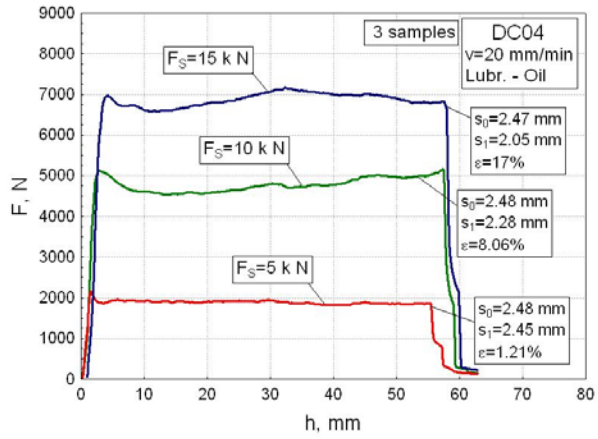

Fig.2 Drawing force dependence on sliding length, case

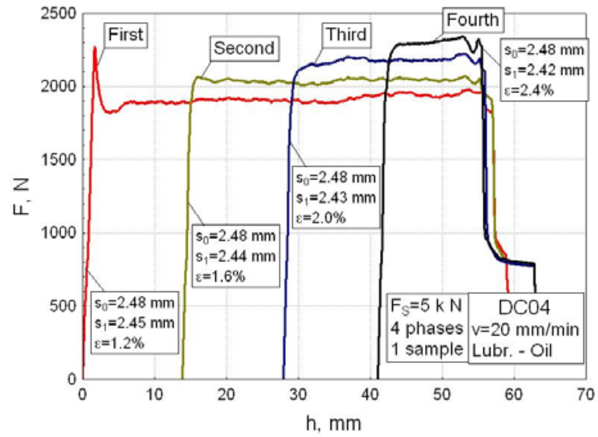

Fig.3 Drawing force dependence on sliding length, case 2

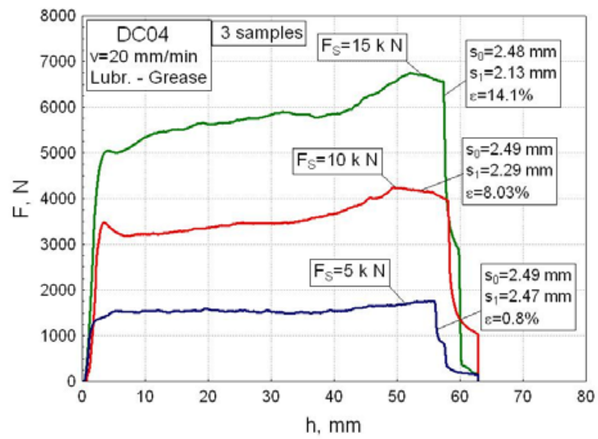

Fig.4 Drawing force dependence on sliding length, case 3

After consideration of previous experimental examples conclusion can be made that constant intensity of lateral force FS simply cause constant thinning deformation, i.e. constant thickness on corresponding length. Question is, is it possible to realize variable thinning deformation, i.e. variable thickness in course of single sliding, on single sliding length? Authors are trying to make proper answer to previous question in next chapter.

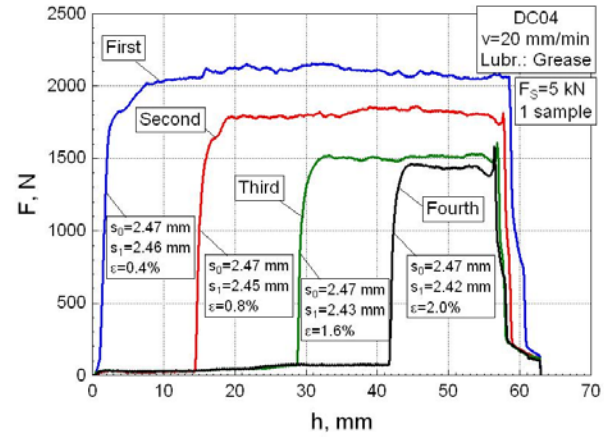

Fig.5 Drawing force dependence on sliding length, case 4

3 THINNING WITH VARIABLE FORCE

After consideration of ironing sliding process in double side thinning model, seems obvious that crucial role act lateral force FS in thinning process. If there is demand for variable thickness on single sliding length can be concluded that continuously variable intensity of lateral force FS can fulfill previous demand. Interaction of lateral force and other influencing factors in ironing process remain open question and subject of further experimental research.

Here, authors were proposed 4 nonlinear functional lateral force FS dependencies on time (i.e. sliding length), Fig. 6 and Fig. 7, and 2 linear dependencies, Fig. 8.

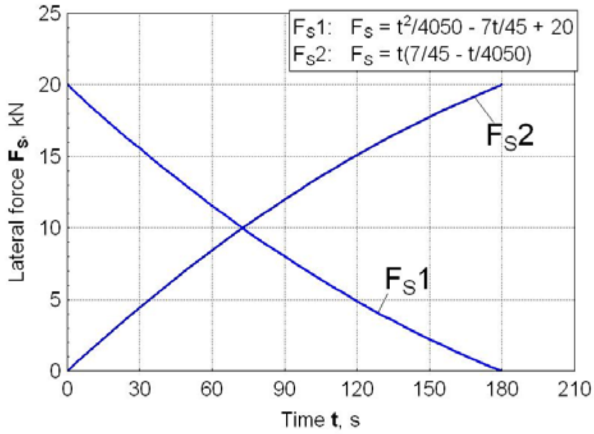

Fig.6 Theoretic lateral force dependence on time, types 1 and 2

Functions are determined according to experimental frame which makes lateral force FS intensity and process lasting (see Figures 2, 3, 4 and 5). Expectation is that variable lateral force can cause approximately similar intensity of thinning deformation like constant FS.

Authors are planning further extensive experimental research towards explaining all the interactions in ironing process of this kind.

Although real appropriate experiment missing, anyway can be used data from experiments with constant intensity of lateral force FS (Figures 2-5). Concerning to that are formed Fig.9 which shows all the achieved thinning deformations in examples on Figures 2-5. Useful are cases related to one sample-one lateral force process type. In this cases achieved are higher thinning deformation intensities.

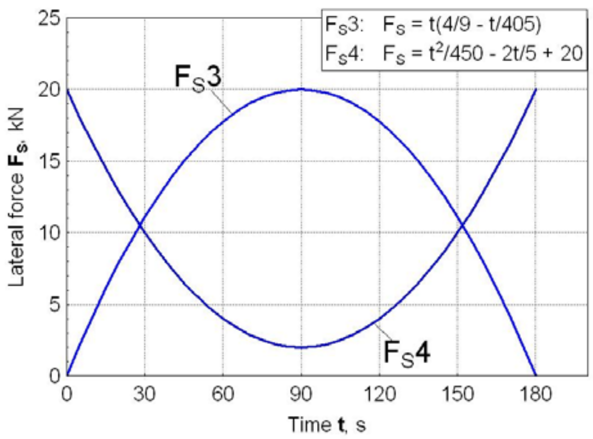

Fig.7 Theoretic lateral force dependence on time, types 3 and 4

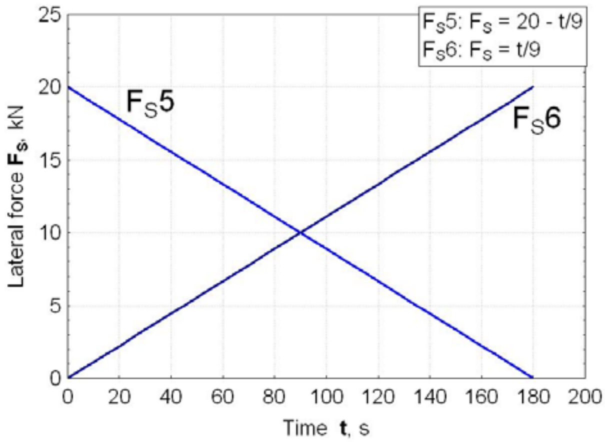

Fig.8 Theoretic lateral force dependence on time, types 5 and 6

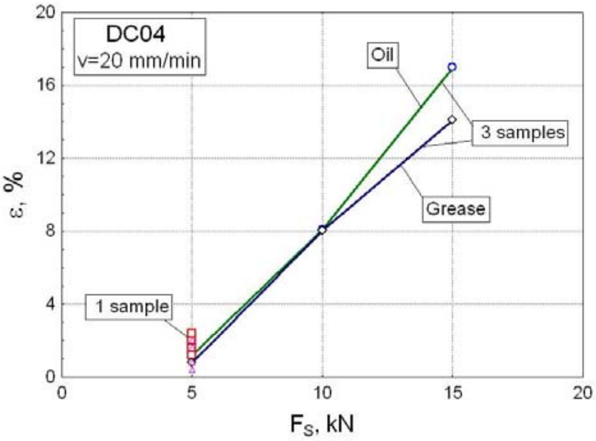

Fig.9 *Thinning deformation dependence on constant lateral force*

Figures 10, 11 and 12 shows hypothetic situation. Considered are variable lateral force type FS2 (Fig. 6) in range 0-15 kN, but used are according thinning deformations from experiment with constant force FS. It is first rough approximation, but only that data we have at the moment, until realization of planned extensive experimental research.

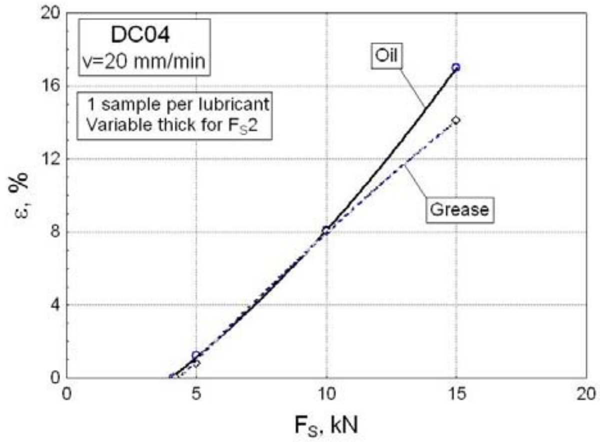

Fig.10 *Thinning deformation dependence on variable lateral force*

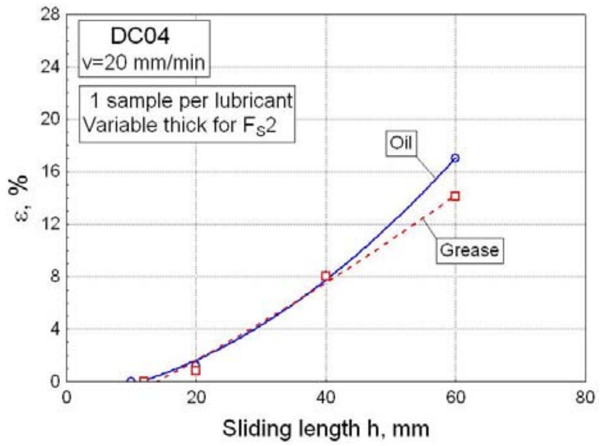

Fig.11 *Thinning deformation dependence on sliding length (variable lateral force)*

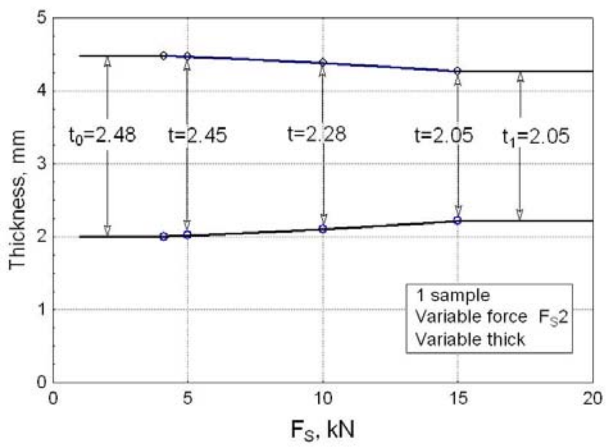

Fig. 12 *Thickness dependence on variable lateral force*

If is previous premise true, Figs. 10, 11 and 12 shows that can be achieve variable thickness according to lateral force function of continuously variable intensity during the ironing process.

4. CONCLUSIONS

Researches of ironing process conducting mainly on experimental laboratory models in conditions of constant lateral forces intensity. Such force cause uniform thinning, i.e. constant thickness on related single sliding length.
Here, in this article, authors were made demand to achieve variable thickness on single sliding length. Based on experimental results obtained with constant lateral force, can be concluded that exists real possibility of this significant ironing process improvement.

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REFERENCES

[1] Schlosser, D. (1975). Beeinflussung der Reibung beim Streifenziehen von austenitischem Blech: verschiedene Schmierstoffe und Werkzeuge aus gesinterten Hartstoffen. Bander Bleche Rohre, No. 7/8, p. 302-306. (In German).

[2] Deneuville, P., Lecot, R. (1994).The study of friction in ironing process by physical and numerical modelling. Journal of Materials Processing Technology, Vol. 45, No. 1-4, p. 625–630. DOI: https://doi.org/10.1016/0924-0136(94)90409-X

[3] Andreasen, J.L., Bay, N., Andersen, M., Christensen, E., Bjerrum, N. (1997). Screening the performance of lubricants for the ironing of stainless steel with a strip reduction test, Wear,Vol. 207, No. 1-2, pp. 1-5.

[4] Sulaiman, H., Christiansen, P., Bay, N. (2017). Influence of tool texture on friction and lubrication in strip reduction, Procedia Engineering, No. 207, p. 2263–2268.
DOI: https://doi.org/10.1016/j.proeng.2017.10.992

[5] Ustunyagiz, E., Nielsen, C., Christiansen, P., Martins, P., Bay, N. (2017). Continuous Strip Reduction Test Simulating Tribological Conditions in Ironing, Procedia Engineering, No. 207, p. 2286–2291.
DOI: https://doi.org/10.1016/j.proeng.2017.10.996

[6] Ozawa, T., Kuboki; T., Kajikawa, S., Yamauchi, A., Gunji, A., Onishi, K. (2018). Fabrication of ring groove on inner surface of cylindrical blank by ironing from outer surface, Procedia Manufacturing,

No. 15, p. 899–906.
DOI: https://doi.org/10.1016/j.promfg.2018.07.407

[7] Aleksandrović, S., Đorđević, M., Stefanović, M., Lazić, V., Adamović, D., Arsić, D. (2014). Different Ways of Friction Coefficient Determination in Stripe Ironing Test, Tribology in industry, Vol. 36, No. 3, 2014., p. 293-299.(Project TR 34002)

[8] Djordjević, M., Aleksandrović, S., Lazić, V., Stefanović, M., Nikolić, R., Arsić, D. (2013). Experimental analysis of influence of different lubricants types on the multi-phase ironing process, Materials Engineering - Materiálové inžinierstvo, Vol. 20, No. 3, p. 147-152.

[9] Djordjevic, M., Aleksandrovic, S., Lazic, V., Arsic, D., Stefanovic , M., Milosavljevic, D. (2015). Two-phase ironing process in conditions of ecologic and classic lubricants application, Proceedings of International conference on Tribology SERBIATRIB 2015, May 13–15, Belgrade, Serbia, p. 407-413.

[10] Djordjevic, M., Aleksandrovic, S., Arsic, D., Lazic, V., Nikolic, R., Hadzima, B., Kotes, P. (2015). Investigation of the lubricants influence on the ironing process, Procedia Engineering, No. 111, p. 149 – 154.

[11] Đorđević, M., Arsić, D., Aleksandrović, S., Lazić, V., Milosavljević, D., Nikolić, R. (2016). Comparative study of an environmentally friendly single-bath lubricant and conventional lubricants in a strip ironing test, Journal of Balkan Tribological Association, Vol.22, No.1A-II, p. 947-958.

[12] Djordjević, M., Aleksandrović, S., Lazić, V., Arsić, D., Nikolić, R., Hadzima, B. (2016). Investigation of the lubrication influence on single-phase and multi-phase ironing processes, Procedia Engineering, No. 149, p. 40 – 47.

[13] Djordjević, M., Aleksandrović, S., Arsić, D., Lazic, V. (2017). Experimental-numerical analysis of contact conditions influence on the ironing strip drawing process, Industrial lubrication and tribology, Vol. 69, Issue 4, p. 464-470. DOI: https://doi.org/10.1108/ILT-05-2016-0113

[14] Djacic, S. (2016). Metal forming with double sided ironing, (In Serbian). Master thesis. Faculty of Engineering, University of Kragujevac.

[15] Aleksandrović, S., Đačić, S., Stefanović, M., Đorđević, M., Lazic, V., Arsić, D. (2017). Influence of process parameters on the friction coefficient in one and multi phase steel strip drawing ironing test, Proceedings of DEMI 2017 Electrical and Mechanical Engineering and Information Technology, May 26-29, Banja Luka, p. 77-86.

[16] Aleksandrović, S., Đačić, S., Đorđević, M., Ratković, N., Arsić, D., Lazić, V. (2020). New method of defining of process parameters in double side thinning strip ironing test, Tribology in industry, Vol. 42, No.1, p. 59-69. DOI:https://doi.org/10.24874/ti.2020.42.01.06 (Project TR 34002)

NOTE

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