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Research article

Determination of the Friction Coefficient by Using 2D and 3D Parameters of the Tools

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ABSTRACT

Current work includes the learning influence of friction in deep drawing process. Friction measurements were also conducted using a modified tribotester based on strip sliding between tools. Four different tool surfaces were tested under similar contact conditions regarding contact area, normal pressure, sliding speed, lubricant and surface characteristics to calculate the friction coefficient between the tool surface and a high strength low alloy steel sheet HSLA 420.

The results showed that friction coefficient varies over a wide range with different lubricating conditions and different sliding velocities. For some sliding velocities, the coefficient of friction is stable and low, while for others it is unstable and higher.

The results have only small dispersion within the different test series, which indicates a stable process with good repeatability. The test method enables comparison of different surface finishes and treatments, lubricants and coatings in terms of friction under conditions similar to those found in sheet metal forming processes. The main difference among the tested tools in this work was the surface roughness, which was found to have a strong influence on friction.

1. INTRODUCTION

The global necessity to increase the effectiveness and stability of technological processes, as well as machines and devices, causes parts of machines and tools to work in increasingly difficult conditions. Ensuring the required durability and performance of machine parts and tools is a challenge for surface engineering. At the same time, requires excellent knowledge of wear mechanisms. The tribological characteristics of surface layers may be improved or modified by coatings, changing the microstructure of surface layers and so on. Therefore, the method must be chosen individually, depending on material, roughness of tool surface, working conditions and predicted friction mechanisms [1,2].

Also, different tribological tests were carried out, which included the pin-on-disc machine and a developed modified strip drawing test, both aimed to simulate behaviour and to investigate the friction between sheet metal and tools during forming [3,4].

2. BRUKER'S NPFLEX 3D OPTICAL MICROSCOPE

Bruker's 3D optical microscopes have targeted automation and analysis capabilities that can save the time. Figure 4. shows the Bruker's NPFLEX 3D optical microscope, general view and close up, used in current work [5,6].

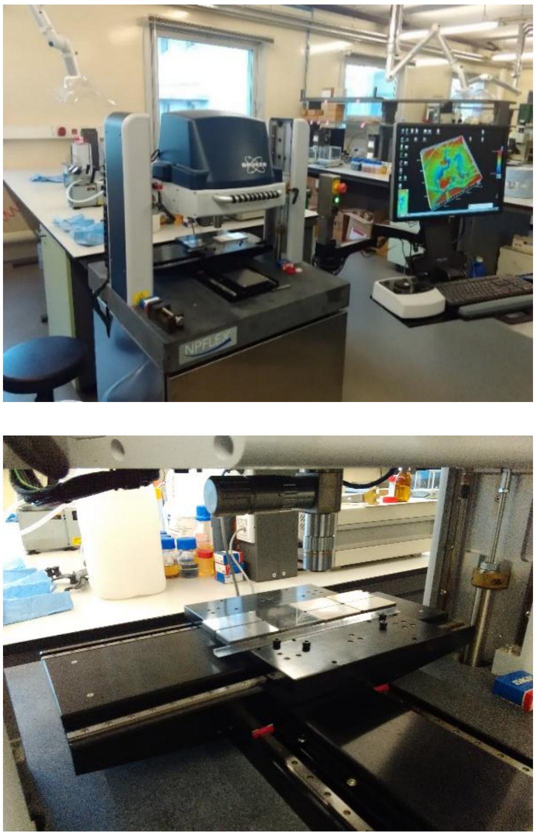


Fig. 1. Bruker's NPFLEX 3D optical microscope; its large nominal working volume handles small or large sample coupons and multi-sample trays.

Bruker 3D optical microscopes provide accurate, adequate measurements of surface roughness. Optical profiling measures surface roughness and shape using the interference of light, resolving surface anomalies from millimeter-scale step heights through nanometer-scale roughness. The 3D analysis allows the estimation of hundreds of parameters to completely describe surface roughness.

Acquiring image and characterising sample surfaces on the micrometer and nanometer scale is key to attaining a functional understanding of a wide range of materials. In fields, such as optics, image acquisition is also critical to the production process. Figure 5 presents the sampling area for measuring 3D surface texture of a tool plate.

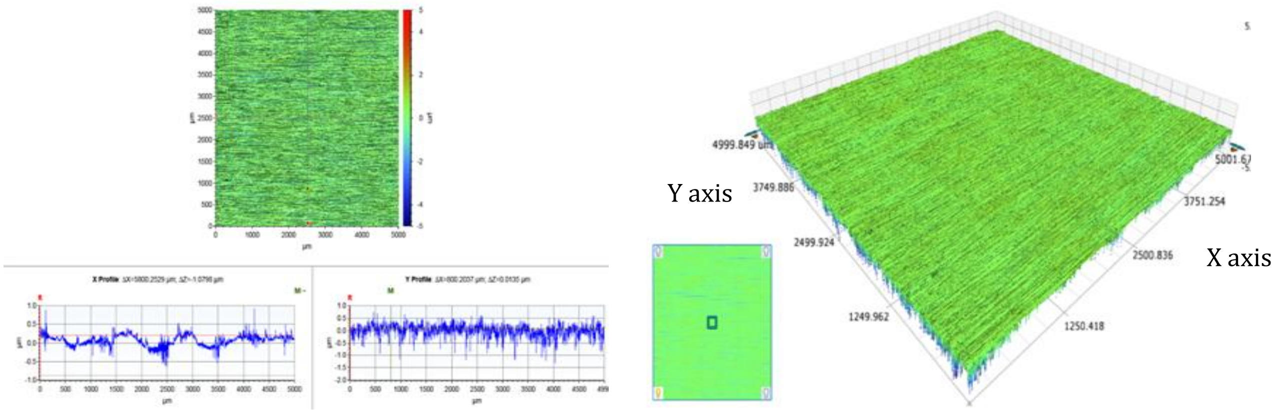
Fig. 2. Measured surface area 5x5 mm2, tool surface Grinded along the Sliding direction

The use of 3D instrumentation with higher resolution provides more accurate surface measurements of forms with complex geometries which in turn means that quantitative surface quality controls can be performed. The values of these measured parameters are presented in Table 1 and Table 2 and the complete parameters are illustrated in Annex B. Considered parameters are roughness average , the surface kurtosis, the highest peak of the surface the root mean square roughness parameter, the surface skewness, the maximum pea depth and the 10-point peak to valley surface roughness. The results of surface roughness measurements clearly show that the used steel sheets have narrow range of parameter value [4,5,7,8].

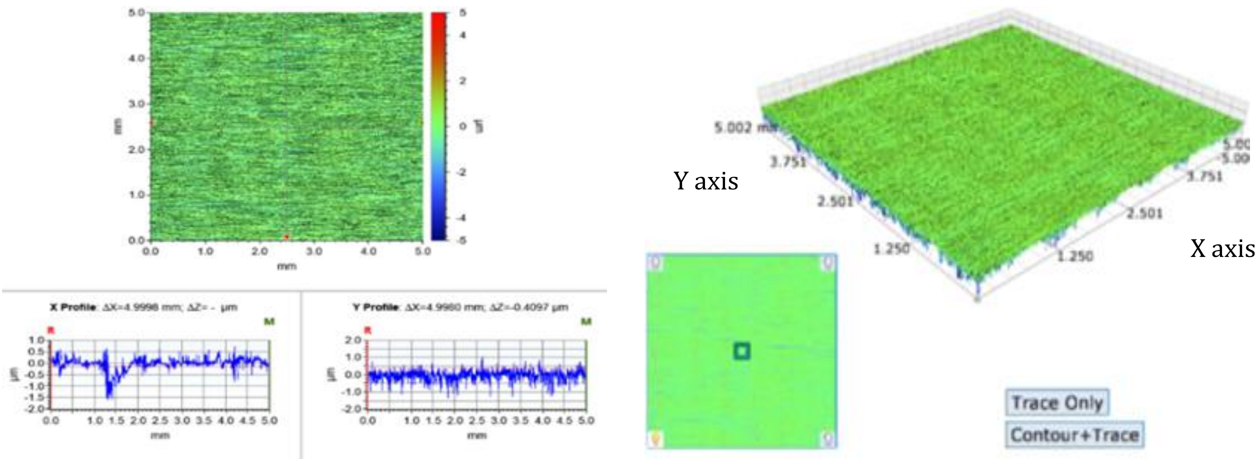
It seems that this allows determination of the effect of mechanical properties of the sheets on the value of friction coefficient.

Tool surfaces measurement had been conducted before and after friction tests. After friction tests in grinded surfaces, a quality of the previous condition is much better than other surfaces finishes.

In sheet metal forming the analysis of conditions of tool surface is a challenging issue. However, a number of techniques is available to handle the challenges with a special focus on lowering costs and improving reliability. With large sample area, analysis cap and automatic data acquisition capabilities, 3D optical microscopes have good solutions.

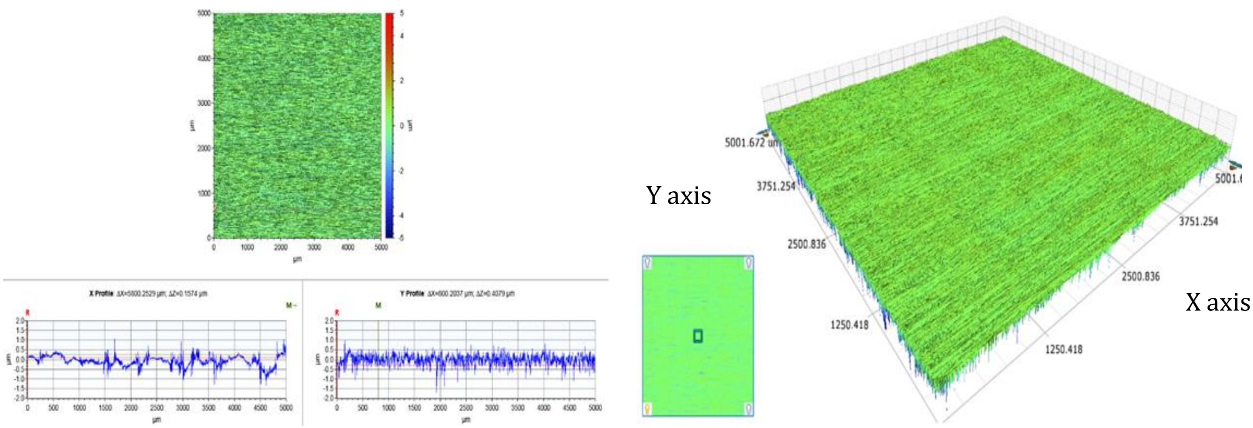


(a) Before tests, X Profile: $\Delta X = 58000.2529$ µm; $\Delta Z = -1.0798$ µm, Y Profile: $\Delta X = 800.2037$ µm; $\Delta Z = 0.0135$ µm

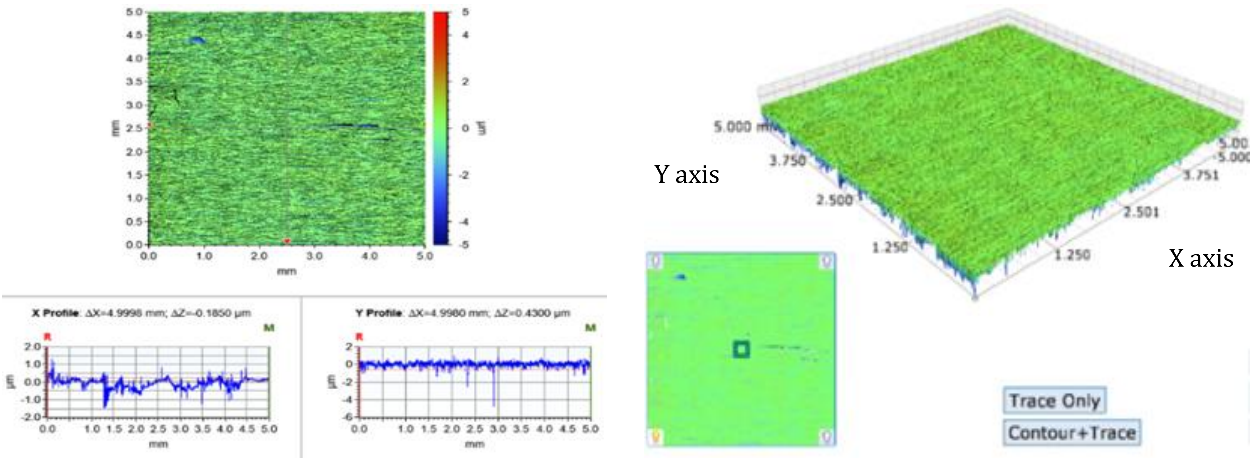


(b) After tests, X Profile: $\Delta X = 4.9998$ µm; $\Delta Z = -$ µm, Y Profile: $\Delta X = 4.9980$ µm; $\Delta Z = -0.4097$ µm

Fig. 3. 3D analysis of a surface of a profile of Grinded "L" tool.



(a) Before tests, X Profile: $\Delta X = 58000.2529$ µm; $\Delta Z = 0.1574$ µm, Y Profile: $\Delta X = 800.2037$ µm; $\Delta Z = 0.4079$ µm



(b) After tests, X Profile: ΔX=4.9998 μm; ΔZ= -0.1850 μm, Y Profile: ΔX=4.9980 μm; ΔZ=0.4300 μm

Fig. 4. 3D analysis of a surface of a profile of Grinded "R" tool.

Table 1. Surface roughness parameters of the tested tools before tests.

Tool surface roughness parameters							
Surface condition	Sa	Sku	Sp	Sq	Ssk	Sv	Sz
	μm		μm	μm		μm	μm
Grinded "L"	0.18	0.008	5.62	0.25	-0.001	-3.14	8.76
Grinded "R"	0.19	0.007	9.20	0.26	-0.001	-3.17	12.37
Polished "L"	0.04	0.053	3.12	0.06	-0.004	-2.22	5.33
Polished "R"	0.06	0.057	8.81	0.11	-0.005	-2.64	11.45
Nitrided "L"	0.76	0.005	16.28	0.97	0.000	-9.09	25.37
Nitrided "R"	0.80	0.003	8.83	1.01	0.000	-8.26	17.09
Quenched/tempered "L"	0.17	0.009	5.37	0.24	-0.001	-4.24	9.61
Quenched/tempered "R"	0.20	0.009	2.22	0.28	-0.001	-9.91	12.13

L- Left plate; R-Right plate

Table 2. Surface roughness parameters of the tested tools after tests.

Tool surface roughness parameters							
Surface condition	Sa	Sku	Sp	Sq	Ssk	Sv	Sz
	μm		μm	μm		μm	μm
Grinded "L"	0.19	0.006	7.36	0.25	-0.0007	-2.84	10.20
Grinded "R"	0.21	0.035	14.82	0.31	-0.0031	-6.36	21.18
Polished "L"	0.04	0.435	11.18	0.07	-0.0087	-6.34	17.52
Polished "R"	0.06	9.563	27.45	0.13	0.0461	-8.71	36.16
Nitrided "L"	0.70	0.005	35.15	0.89	-0.0004	-11.98	47.13
Nitrided "R"	0.71	0.004	35.39	0.90	-0.0003	-12.87	48.26
Quenched/temp "L"	0.18	0.012	14.67	0.24	-0.0013	-3.82	18.48
Quenched/temp "R"	0.20	0.011	20.09	0.28	-0.0012	-3.51	23.60

L- Left plate; R-Right plate

3. D MEASURING METHOD USING CONTACT DEVICE HOMMEL TESTER T500

The contact roughness measuring device corresponds to a simple measurement and to a standard in the class of mobile roughness measuring instruments. With just two keys and one thumb wheel, the HOMMEL TESTER T500 is easy to handle in production [3,9-11]. The instrument calculates all common parameters and monitors the tolerance limits set for them. The measurement results can be saved in the instrument and can be evaluated by the Windows software TURBO DATAWIN.

Measuring surface roughness and quality surfaces are traditionally estimated by the naked eye and measured by mechanical profilers for surface roughness, commonly described with the Ra, Rz, Rmax or Rt values. Typical output parameters are the Ra (arithmetic mean value of a profile), the Rz (mean peak to valley height) and the Rmax (or Rt, the maximum peak to valley height) [12,13].

In 2D measuring method two different direction, were used as seen in Figure 8: first position is measured along to sliding direction of friction test; second position is measured perpendicular to sliding direction. From Table 3 to Table 6 measured results are presented for Grinded “L” and Grinded “R” surfaces Before and After tests. The values of these measured parameters for the other tested surfaces are illustrated in Annex B.

Fig. 5. Method of measurement of tool surface with traditional HOMMEL TESTER T500.

Table 3. Grinded “L” surface parameters - Before tests.

Grinded “L”	Measurement along to sliding direction			Measuring perpendicular to sliding direction		
Order of tests	RmD µm	RzD µm	Ra µm	RmD µm	RzD µm	Ra µm
1	0.69	0.48	0.07	1.90	1.34	0.14
2	1.01	0.64	0.09	1.44	1.21	0.13
3	0.82	0.65	0.10	1.71	1.32	0.12
Average	0.84	0.59	0.09	1.68	1.29	0.13
Optical microscope	1.61	1.20	0.09	2.23	1.86	0.18

Table 4. Grinded “L” surface parameters - After tests.

Grinded “L”	Measurement along to sliding direction			Measuring perpendicular to sliding direction		
Order of tests	RmD µm	RzD µm	Ra µm	RmD µm	RzD µm	Ra µm
1	0.94	0.70	0.10	1.62	1.16	0.12
2	0.92	0.72	0.10	1.60	1.14	0.12
3	0.60	0.52	0.08	1.54	1.28	0.14
Average	0.82	0.65	0.09	1.59	1.19	0.13
Optical microscope	1.63	1.25	0.10	2.17	1.83	0.18

Table 5. Grinded “R” surface parameters - Before tests.

Grinded “R”	Measurement along to sliding direction			Measuring perpendicular to sliding direction		
Order of tests	RmD µm	RzD µm	Ra µm	RmD µm	RzD µm	Ra µm
1	0.75	0.66	0.11	1.63	1.28	0.14
2	0.57	0.50	0.09	1.30	1.19	0.13
3	1.12	0.81	0.12	1.60	1.15	0.13
Average	0.81	0.66	0.11	1.51	1.21	0.13
Optical microscope	1.66	1.28	0.11	2.39	1.92	0.18

Table 6. Grinded "R" surface parameters - After tests.

Grinded "R"	Measurement along to sliding direction			Measuring perpendicular to sliding direction		
Order of tests	RmD µm	RzD µm	Ra µm	RmD µm	RzD µm	Ra µm
1	0.76	0.68	0.10	1.70	1.30	0.14
2	1.12	0.78	0.10	1.76	1.38	0.14
3	0.74	0.56	0.08	1.14	1.00	0.12
Average	0.87	0.67	0.09	1.53	1.23	0.13
Measured by optical microscope	1.83	1.35	0.12	3.24	2.16	0.20

4. CONCLUSIONS

Friction measurements were conducted using a modified developed tribotester based on flat strip drawing. Four different tool surfaces were tested under similar contact conditions regarding contact area (2746 mm2), normal force, sliding speed, lubricant and surface characteristics to calculate the friction coefficient between the tool surfaces and steel sheet HSLA 380. The applied normal load was defined from 10 to 49 kN and the sliding speed from 60 mm/min to 240 mm/min.

This research deals with tribological tests carried out using pin-on-disc machine and determination of coefficient of friction and behaviour between sheet metal and tools during forming. It was considered frictional characterization of reciprocating sliding tests and the effect of lubricant and other variables on the coefficient of friction of the cold rolled HSLA 380 and cold rolled HSLA 420 steel sheets with a set of two Prelube oils and its combination with five Press oils.

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