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The Theoretical Analysis of Wire Drawing Process for Hydrodynamic Friction Conditions

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In the work has been shown the theoretical analysis the influence of different friction coefficients on strain intensity, redundant strain and temperature distribution for drawn wires, on the base of drawing process simulation with use of finite element method.

Keywords: DRAWING, PRESSURE DIES, FRICTION COEFFICIENT, FINITE ELEMENT METHOD

Introduction

Among many known methods, which can be use in the practice for wires productions, we can distinguish two fundamental: the conventional drawing process with use of stable dies and another one which can improve the friction conditions with use of pressure drawing die. In conventional method of drawing, the process is realized in dry friction conditions or mixed friction. In such type of process the friction coefficient is carried as a measure of friction, the value is higher than 0.05. During drawing process by pressure dies the direct contact between the wire and die surface cannot be observed, and the value of friction coefficient should be lower than 0.05.

Disadvantageous influence of friction during drawing process discloses in non-uniform distribution of strain intensity for drawn material, and causes non-uniform distribution of mechanical properties on wire cross section. The non-uniform distribution of temperature in deformed material is another negative result of friction.

In many authors opinion [1-4], the wire drawing process for conventional method of drawing take place in dry or mixed drawing conditions. For the measure of friction in such realized process the value of friction coefficient higher than 0.05 is established. The surfaces of material and die in drawing cone of the die during dry drawing process have the direct contact. But in wire drawing process by pressure dies, for conditions which are bettering the lubrication, the direct contact between wire and die surface shouldn't be observed, the value of friction coefficient have to be lower than 0.05.

Nowadays in applied dies for hydrodynamic drawing processes, by the aim of pressure increasing, the lubricant mediums which have considerable coefficient of dynamic viscosity, such soaps are used.

The construction and scheme of wire drawing process with use of pressure dies shown on **Figure 1**.

The pressure die is composed of back-up drawing die and working die, which are separated by packing and closed in container. During drawing process the lubricant molecules are adhering to wire surface and next they are inserting to the pressure chamber by thin gap (about 0.2 mm) between wire and resistant die, producing the hydrodynamic effect. Until the moment of pressure increase till the yield point of drawing wire we can observe the hydrodynamic friction in working die and the lubricant fully separates the rubbing surfaces.

The force for overcoming the friction for the hydrodynamic friction conditions decreasing and the total force of drawing is becoming smaller, too. The investigation [6, 7] shown that for drawing process with use of pressure dies the drawing force is 20 to 30% smaller than for conventional drawing processes. Such situation influences on final wires properties. Lower values of drawing force cause that effort coefficient (ratio the drawing stress σ_c to yield point) is for wires drawn by pressure dies about 10% lower than for wires drawn on conventional way.

Disadvantageous influence of friction during drawing processes can be observed by the non-uniform distribution of strain intensity and by the redundant strain, it causes the non-uniform distribution of mechanical properties on wire cross section and the appearance the I kind internal stresses.

The complementary, longitudinal I kind internal stresses, which remained after drawing process has the essential influence on mechanical and technological properties of wires, because the stresses from external forces and longitudinal, tensile internal stresses will have an impact on material's plasticity.

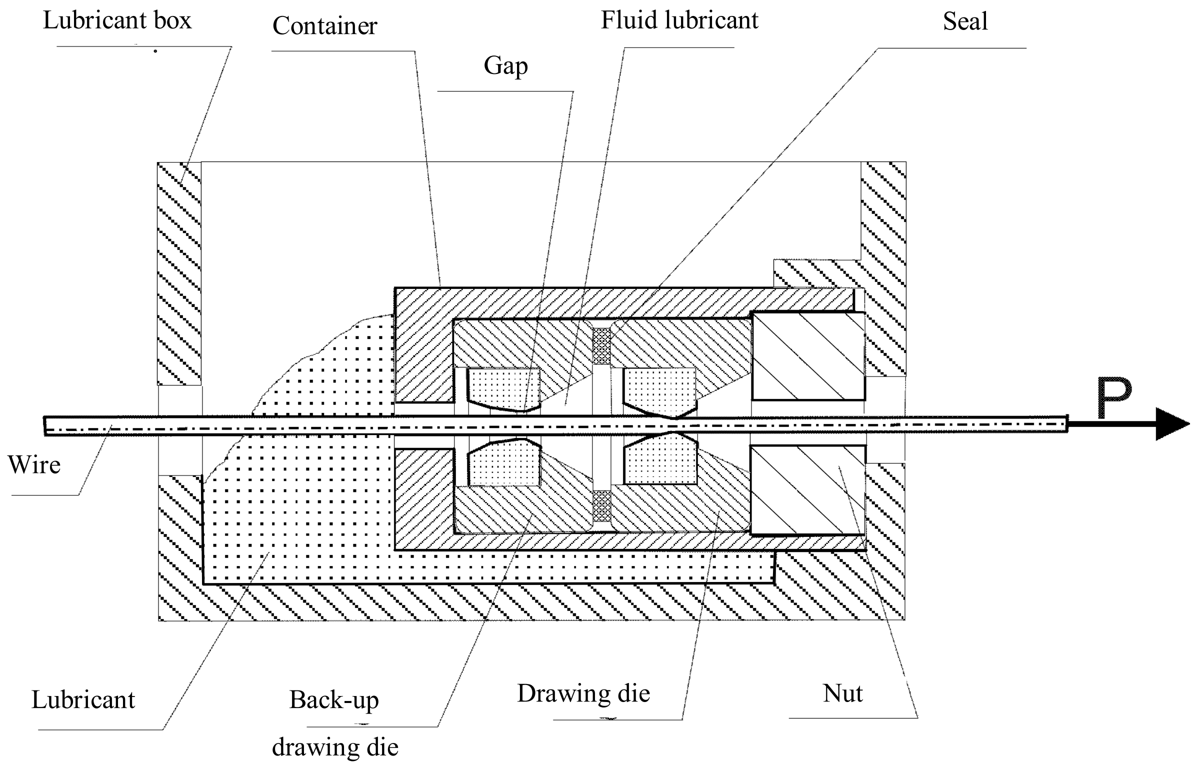


Figure 1. Construction and the scheme of drawing process with use the pressure die [5]

So material's effort is an effect of external stresses and internal stresses which remain after drawing process.

The non-uniform distribution of wire temperature is another negative result of friction exiting in deformed material. The non-uniform distribution and high gradient of temperature on the wire cross section cause the occurring the thermal stresses what influences on wire properties, for example on value of fatigue strength.

Research

Determination of redundant strain, the distribution of temperature and strain intensity on the base of theoretical equations or on the base of experimental research is very difficult, so the investigations concerned with simulation of hydrodynamic drawing process with use of finite element method has been done.

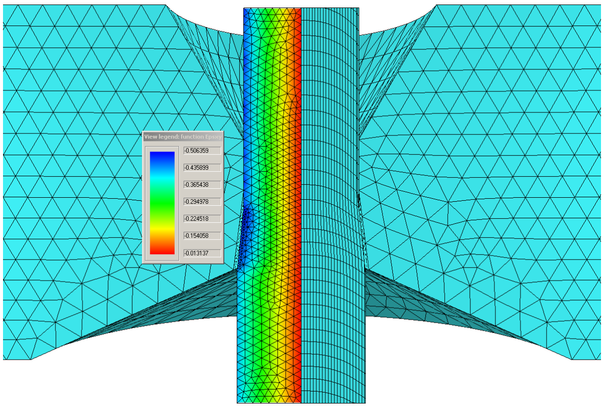
The simulation of the process was carried out with use of computer program Drawing 2D [8, 9], to shown in which range the drawing process by pressure dies influences on strain intensity, and surface layer redundant strain and the decrease of wire temperature.

The drawing process was realized for wires from C75D steel drawn from initial diameter 4.0 mm in 6 draft to final diameter 1.70 mm, with drawing speed equal 1.6 m/s, with use drawing dies of an angle of $2\alpha=12^o$. For variant I the friction coefficient equal 0.06, and for variant II 0.006.

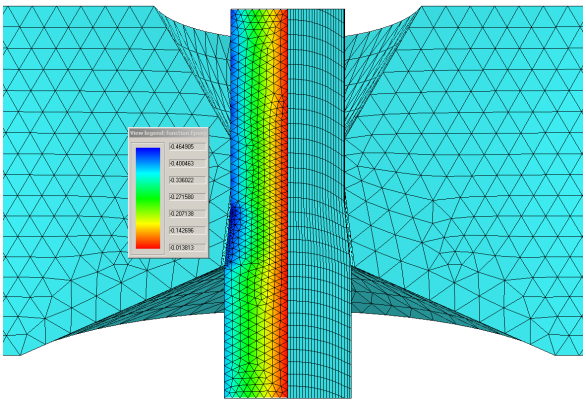
Results of theoretical analysis shown the change of strain intensity for wire surface ε_{csurf}, and for wire axis ε_{caxis}, redundant strain on wire surface ε_{xy}, wire surface temperature T_{surf}, wire axis temperature T_{axis}, an average wire temperature T_{av} shown in **Table 1** and on **Figure 3-5**, the examples of redundant strain ε_{xy} for the last draft for both variants of drawing process shown on **Figure 2**.

Table 1. The change of strain intensity, redundant strain and temperature in total reduction function

Draft no	1	2	3	4	5	6
D, mm	3.40	2.93	2.53	2.18	1.90	1.70
G_c, %	27.8	46.3	60.0	70.3	77.4	81.9
Parametr			Variant I $\mu = 0.06$			
ε_{csurf}	0.347	0.669	0.988	1.303	1.588	1.819
ε_{caxis}	0.314	0.587	0.855	1.121	1.368	1.557
ε_{xy}	-0.092	-0.172	-0.256	-0.338	-0.419	-0.462
T_{surf}, °C	288.7	318.4	326.6	335.4	329.1	288.9
T_{axis}, °C	111.6	121.7	129.2	135.8	134.1	114.9
T_{av}, °C	156.4	167.5	178.2	188.7	190.2	172.2
			Variant II $\mu = 0.006$			
ε_{csurf}	0.344	0.657	0.960	1.291	1.562	1.781
ε_{caxis}	0.318	0.598	0.870	1.147	1.393	1.590
ε_{xy}	-0.074	-0.149	-0.224	-0.306	-0.382	-0.423
T_{surf}, °C	166.5	181.6	188.3	197.2	193.6	176.1
T_{axis}, °C	113.4	124.2	132.2	139.5	136.0	118.9
T_{av}, °C	136.4	148.7	158.2	165.1	167.3	149.4



a



b

Figure 2. The distribution of redundant strain ε_{xy} for wires drawn from diameter 1.90 mm on diameter 1.70 mm: *a* – variant I; *b* – variant II

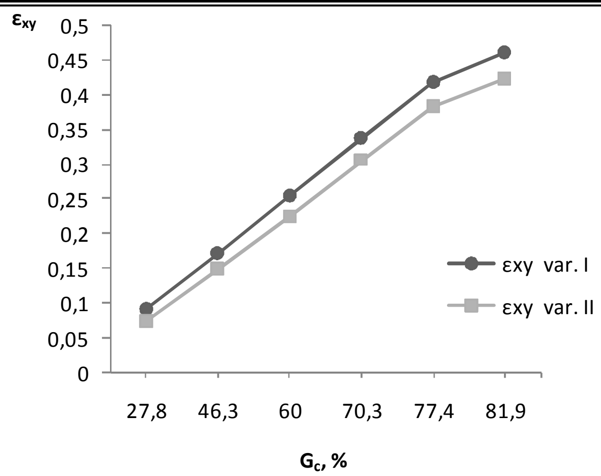


Figure 3. The change of redundant strain ε_{xy} for wire surface drawn in conventional way (variant I) and with use of pressure dies (variant II) in total reduction function

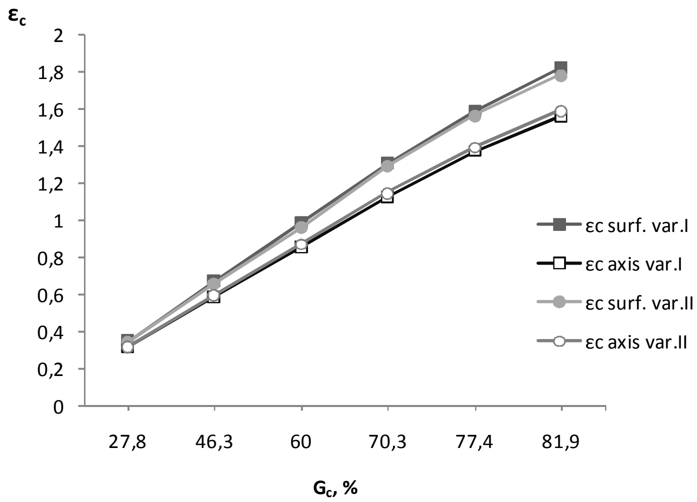


Figure 4. The change of strain intensity on wire surface and on wire axis for wires drawn in conventional way (variant I) and with use of pressure dies (variant II) in total reduction function

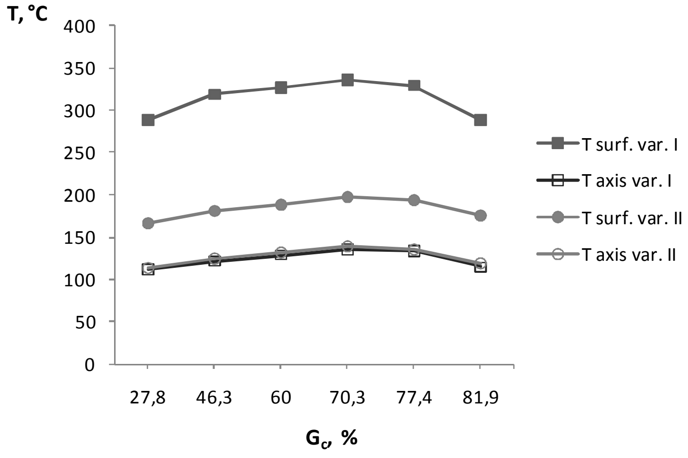


Figure 5. The change of temperature for wire surface and for wire axis for wires drawn in conventional way (variant I) and with use of pressure dies (variant II) in total reduction function

Conclusions

On the base realized theoretical research we observe the decreasing the redundant strain values for wire surface by 8.5% for wires drawn in hydrodynamic friction conditions.

Such situation influences on the increase strain uniformity, and on the decrease of strain intensity for wire surface by 2.0%, and the increase for wire axis by 2.1%.

For wires drawn by pressure dies the temperature for wire surface and average temperature decreased.

But for wire axis we observe the insignificant increase by 2-4ºC, what is caused by the increase of strain intensity for wire axis.

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Теоретический анализ процесса волочения для условий гидродинамического трения

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В работе приведен теоретический анализ влияния различных значений коэффициента трения на интенсивность напряжений, дополнительная деформация и распределение температуры в проволоке на основе моделирования процесса волочения с использованием метода конечных элементов.