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The numerical analysis of Hi-temp 095 wire drawing process

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Analysis and modelling

ABSTRACT

Purpose: The aim of this paper was the optimization of wire drawing process parameters.
Design/methodology/approach: The hard binding material determined according to American standard ANSI/AWSA 5.8-92 as High-temp 095 was chosen to the analysis of wire drawing process. It is hard solder with high fluidity properties.
Findings: Wires, bars and strips are the most often use forms of this solder on the base of copper with low deformability properties, which shows crack sensitivity during cold plastic working processes so there was the necessity to determining optimal parameters of initial material use to the later cold plastic working processes.
Research limitations/implications: To the numerical analysis of Hi-temp 095 wire drawing process the Drawing 2d programme based of finite element method, has been use, for initial materials obtained on the casting and extrusion way.
Practical implications: The optimal properties of basic material use for further plastic working processes were determined.
Originality/value: The rheology of materials after casting and extrusion processes were determined.
Keywords: Computational material science; Wire drawing; Solders

1. Introduction

Soldering process is one of the main method of joining metals in electronics, elektrotechnics and telecommunications.

Is one of the method guarantees obtaining the joint with physical continuity, made with the solder which melting temperature is lower than melting temperature of joined materials.

The development of new joining technologies and soldering technologies too, was the necessity to determining highly efficient technology of obtaining solders in the wire and bars forms.

Analyzed solder is one of the solder from the group of hard solders, high melting, we use this solder when we expected from soldering joint high mechanical strength properties.

The high soldering properties in soldering process of metals and composite materials and high strength properties of joint results from high contents of manganese in this solder [1-4].

2. Research

2.1. Experimental procedures

The investigations of wire drawing process was made for solder on the base of copper marked according American standards ANSI/AWSA 5.8-92 as Hi-temp 095, with chemical composition placed in Table 1 [5,6].

Table 1.
Chemical composition of Hi-temp 095 alloy

Chemical element	The contents, %
Copper	52.5% ± 1.0%
Nickel	9.5% ± 1.0%
Manganese	Equilibrium
Boron	0.10% Max
Iron	0.10% max
Others elements	0.50% max

2.2. The determination of work-hardening curves for materials obtained on casting and extrusion way

The equation describing of work-hardening curves was determined on experimental research by the axial tension of samples with variables diameter.

To the investigations, samples (five specimens) obtained on the way:

- extrusion, after extrusion process on 8-hole horizontal extrusion press,
- casting, turned from teemed ingot;

were used.

The measurement part of samples was composed of three segments K,L,M with different diameters . The shape of samples was shown on Fig.1.

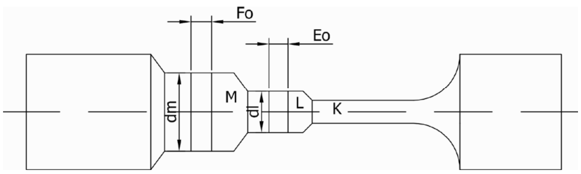

Fig. 1. The shape of the samples used during experimental method of determination the work-hardening curves

To make possible the precisely determination of φ_L and φ_M deformation values of L and M segments, two measurement scratches were putted in the known distance e_0 and f_0 (Fig.1).

After axial tension of the samples during occurring in the thinnest part the sharply outlined reduction of area, the distances e and f were measured.

The deformation L and M segments were calculated according the following equation:

$$\varphi_L = \ln \frac{e}{e_0} \tag{1}$$

$$\varphi_M = \ln \frac{f}{f_0} \tag{2}$$

The yield stresses σ_{pL} and σ_{pM} corresponded to deformations from equation (1) and (2), were equal to tensile stresses which occurred in the final phase of process, that is after obtaining by the axial force maximal value:

$$\sigma_{PL} = \frac{P}{A_L} \tag{3}$$

$$\sigma_{PM} = \frac{P}{A_M} \tag{4}$$

where A_L and A_M – real section of adequate sections of the specimen, which were determined from the condition of constant volume:

$$A_L = \frac{\Pi d_L^2}{4} * \frac{e_0}{e} \tag{5}$$

$$A_M = \frac{\Pi d_M^2}{4} * \frac{f_0}{f} \tag{6}$$

After substituting the A_L and A_M values to the (3) and (4) equations we are getting:

$$\sigma_{PL} = \frac{P}{\frac{\Pi d_L^2}{4} * \frac{e_0}{e}} \tag{7}$$

$$\sigma_{PM} = \frac{P}{\frac{\Pi d_M^2}{4} * \frac{f_0}{f}} \tag{8}$$

In the aim of determination the material parameter n, occurred in the equation describing the equation of work-hardening curve:

$$\sigma_P = C\varphi^n \tag{9}$$

force P was determined from (7) and (8) equations and by comparison the obtaining dependences we were getting the following relation:

$$\sigma_{PL} * d_L^2 * \frac{e_0}{e} = \sigma_{PM} * d_M^2 * \frac{f_0}{f} \tag{10}$$

After substituting the values of yield stresses according the equation (9):

$$\sigma_{PL} = C * \varphi_L^n \tag{11}$$

$$\sigma_M = C * \varphi_M^n \tag{12}$$

The equation (10) has the following form:

$$\varphi_L^n * d_L^2 * \frac{e_0}{e} = \varphi_M^n * d_M^2 * \frac{f_0}{f} \tag{13}$$

After substituting to the (13) equation, equations (1) and (2) we were getting following notation:

$$\left|\ln \frac{e}{e_0}\right|^n * d_L^2 * \frac{e}{e_0} = \left|\ln \frac{f}{f_0}\right|^n * d_M^2 * \frac{f}{f_0} \tag{14}$$

all parameters shown in the equation (d_L, d_M, e_0, e, f_0, f), except exponential index of work-hardening curve, n, are possible to the determination.

After finding the logarithm of (14) equation, the n parameter can be formulate by the following equation:

$$n = \frac{\ln\left[\frac{d_M^2}{d_L^2} * \frac{f_0}{f} * \frac{e}{e_0}\right]}{\left[\frac{\ln \frac{e}{e_0}}{\ln \frac{f}{f_0}}\right]} \tag{15}$$

When we know the value of n parameter we can determine the value of material constant C, according the following equation:

$$\frac{P}{\frac{\Pi d_M^2}{4} * \frac{f}{f_0}} = C * \varphi_M^n \tag{16}$$

The value of constant C equal:

$$C = \frac{P}{\frac{\Pi d_M^2}{4} * \frac{f}{f_0} * \varphi_M^n} \tag{17}$$

According to shown method the work-hardening curves equations were determined to the specimens obtained on the extrusion and casting way.

For material obtained on extrusion way:

$$\sigma_P = 519{,}621 * \varphi^{0{,}291} \tag{18}$$

For material obtained on casting way:

$$\sigma_P = 625{,}467 * \varphi^{0{,}312} \tag{19}$$

On the base of determined equations work-hardening curves for materials obtained on extrusion and casting way were plotted (Fig.2).

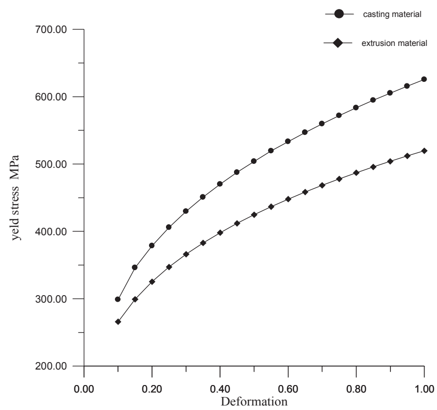

Fig. 2. The work-hardening curves for materials obtained on extrusion and casting way

2.3. The simulation of wire drawing process

Theoretical analysis of drawing process was performed with a help of the Drawing 2d software, which has been elaborated especially for the drawing problem. The drawing process was carried out for the wires with initial diameter ϕ 3.4 mm to the final diameter ϕ 1.70 mm, in six draws on a bull block drawing machine, with the speed of drawing equal v_c=1.6 m/s. The value of friction coefficient equal μ=0.06 [7-15].

The schedule of single and total reductions are shown in Table 2.

Table 2.
The schedule of single and total reductions.

	Draw no 1	Draw no 2	Draw no 3	Draw no 4	Draw no 5	Draw no 6
G_p[%]	27.8	25.7	25.4	25.8	24.0	20.0
G_c[%]	27.8	46.3	60.0	70.3	77.4	81.9

The values of temperature for wires axis and for wires surface for materials obtained on casting and extrusion way in wire drawing process after each draw are shown on Fig.3 and 4, and the values of drawing stresses on Fig.5.

On the base of temperature distribution shown on Fig.3 and 4 we can observe that the temperature values are higher for wire surface then for wire axis, these difference between values is caused by the material deformation inhomogenity on wire diameter and by the friction forces on surface between material and tool, which have a restraining effect on surface layers.

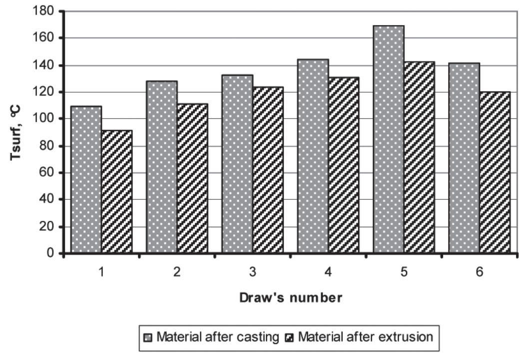

Fig. 3. The values of temperature for wire surface for materials obtained on casting and extrusion way after wire drawing process, for six draws

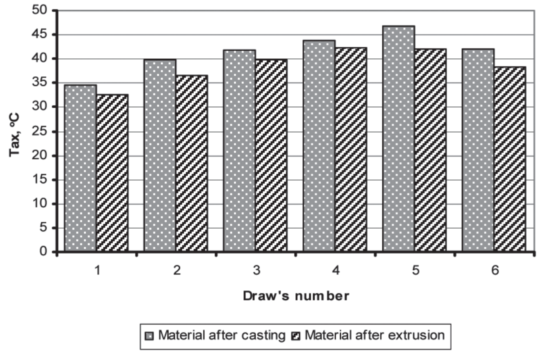

Fig. 4. The values of temperature for wire axis for materials obtained on casting and extrusion way after wire drawing process, for six draws

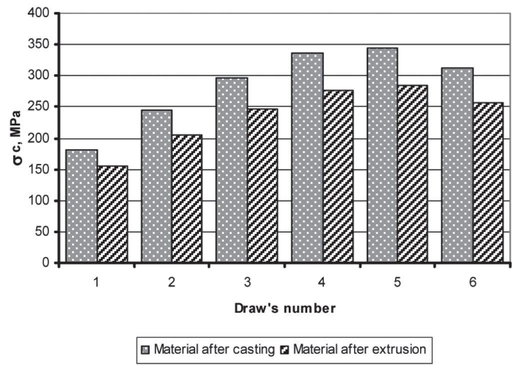

Fig. 5. The values of drawing stresses for materials obtained on casting and extrusion way after wire drawing process, for six draws

For the material obtained on casting way the values of temperature are about 10% higher than for material obtained on extrusion way, for all analyzed parts of wires.

The research results shown that the wires obtained on extrusion way have better plastic properties, because the structure of the material obtained after extrusion process is fine-grained and have very good fibers orientation, whereas the material obtained on casting way is characterized by very large numbers of micro-shrinkages, and structure discontinuities, what have an essential influence on worsening the mechanical and plastically properties of material.

The values of drawing stresses for material obtained on casting way were about 30 MPa higher than for material obtained on extrusion way (for large total reductions even 25%).

3. Summary

The extrusion process of bars from Hi-temp 095 alloy has an essential influence on increasing the material's plasticity what, in wire drawing process, influences on decreasing the material's temperature and drawing stresses. Such good conditions of the process can give the possibility to the realization during wire drawing processes, higher total reductions without additional heat treatment.

References

[1] T. Radomski, A. Ciszewski, Soldering, WNT, Warszawa, 1997 (in Polish).
[2] J. Richert, J. Zasadziński, M. Richert, W. Libura, Plastic Forming Composites in the Semi-Liquid, Archives of Metallurgy 39/1 (1994) 71-85.
[3] J. Richert, Stability Conditions of Metal Flow in Radial Extrusion, Zeitschrift fur Metalkunde 79/4 (1988) 248-251.
[4] J. Richert, The analysis the shape of tool on behavior the stability of flow plasticity during radial extrusion processes. Metallurgy and Casting, 1405, Scientific Review AGH, 135, 1991, 1-104 (in Polish).
[5] Polish Standard ANSI/AWSA5.8-92.
[6] The brazing book – Handy&Harman, Lucas – Milhaupt, South Pennsylvania, USA.
[7] S. Wiewiórowska, P. Wieczorek, The determination of mechanical properties and structure of hi temperature alloy – Hi-temp 095, Proceedings of the XII International Technical-Scientific Conference "Machine-Building and Technosphere of the XXI Century", Donieck National Technical University – Sewastopol, 2005, 287-290.
[8] Z. Muskalski, A. Milenin, Theoretical and experimental analysis the drawing process with the change of drawing direction, Proceedings of the Conference "WireExpo" 2006, WAI, Boston, USA, 2006, 5-10.
[9] W. Weroński, Z. Pater, Plastic working, 1994 (in Polish).
[10] A. Milenin, Z. Muskalski, S. Wiewiórowska, P. Kustra, The multi-scale FEM simulation of the drawing processes of high carbon steel, Journal of Achievements in Materials and Manufacturing Engineering 23/2 (2007) 71-74
[11] B. Mochnacki, M. Ciesielski, Application of Thiessen polygons in control volume model of solidification, Journal of Achievements in Materials and Manufacturing Engineering 23/2 (2007) 75-79.
[12] M. Greger , R. Kocich, L.Cizek, Superplastic properties of magnesium alloys, Journal of Achievements in Materials and Manufacturing Engineering 22/2 (2007) 83-86.
[13] J. Nowacki, Barazing of 14-5 PH steel and WC-Co sinters on considerable dimension structure, Archives of Materials Science and Engineering 28/3 (2007) 173-182.
[14] B. Kosec, G. Kosec, M. Sokovic, Temperature field and failure analysis of die-casting die, Archives of Materials Science and Engineering 28/3 (2007) 182-188.
[15] S. Bingol, M.S. Keskin, Effect of different extrusion temperature and speed on extrusion wells, Journal of Achievements in Materials and Manufacturing Engineering 23/2 (2007) 39-43.