Yugoslav Association of Metallurgical Engineers *UDC:669.715-47:620.17/.18=20*
YAME

MECHANICAL AND STRUCTURAL PROPERTIES OF THE EXTRUDED HOLLOW PROFILES OF Al-ALLOYS*

VELIBOR J.MARINKOVIĆ[1], TOMISLAV R. MARINKOVIĆ[2]

[1]*Faculty of Mechanical Engineering, Niš, Yugoslavia*
[2]*Aluminium Company "NISSAL', Niš, Yugoslavia*

ABSTACT

Hollow profiles of Al-alloys are produced by extrusion in the hot state in the special bridge tools. This technological procedure is characterized by slitting and re-connecting (welding) the workpiece within the die. In the extrusion process very high degrees of deformation are achieved at high temperatures for this kind of material and at considerable strain rates. Individual and interactive effects of these factors upon mechanical and structural properties of the finished product (profile) material are very considerable but they are not sufficiently examined yet. The research presented in this paper refers to alloy AlMgSi0.5 that is considered as representative for all the Al-alloys that can be worked by hot extrusion.

Key Words: Extrusion, (Micro)structure, Al-alloys, Bridge tool, Welding, Tensile Strength

1. INTRODUCTION

Al-alloys profiles find a wide application in air and car industries, then in construction engineering, railway car industry, in the manufacturing of metal furniture, etc [1].

On the basis of profiles and other products made of Al-alloys in the twenties of the last century there was accepted, in Europe, the so-called Light-weight Construction Concept (Leictbau Konzept) [2, 3, 4].

There are various methods of extruding profiles from Al-alloys [5, 6]. The procedure of forward extrusion has found the widest application in practice.

---

* The paper was presented on the Symposium: "Deformation and Structure of Metals and Alloys", June 26-27.2002, Belgrade, Yugoslavia

The form of Al-alloy profiles is defined by their cross-section that can be very complex. For practical reasons, the profiles are most often classified into two groups, namely, into the group of full and the group of hollow profiles.

The method of forward extrusion of hollow Al-profiles belongs to the most complex methods of metal working in general.

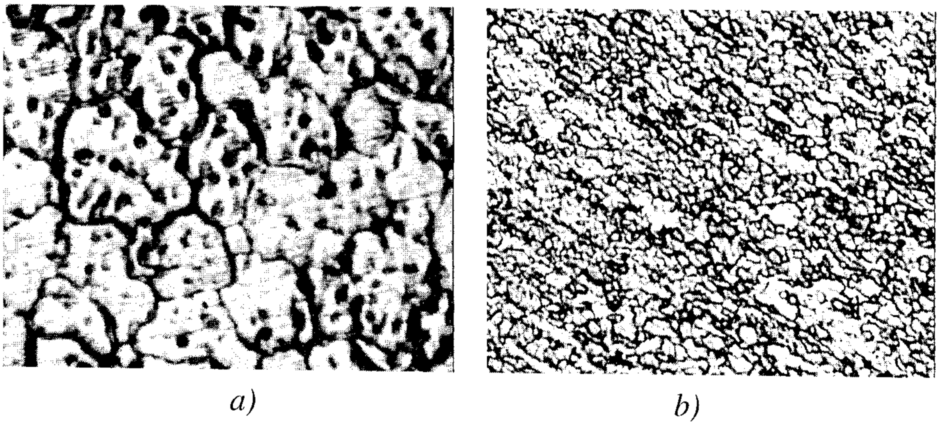
In this paper the influence of the technological factors of the forward extrusion in bridge tools upon structural and mechanical properties of hollow profiles will be discussed.

2. DEFORMATION STATE AT EXTRUSION

With the metal forming conventional processes the examinations of the real material flowing, the stress-strain state, the tribological and other phenomena are usually done in the laboratory conditions. Due to the specific nature of the Al-profile extrusion processes this kind of examination is limited only to the manufacturing conditions which, on one hand, makes the whole procedure difficult while, on the other, it increases the reliability of the obtained results.

For the mentioned research different methods are used, most often the method of measuring meshes [7, 8]. While extruding profiles from Al-alloys the application of this method creates additional difficulties and limitations [9]. It has been shown that for the process under examination, that is, the process of forward extrusion of hollow profiles from Al-alloys the method of "macro-polish" and the microstructural method can be successfully applied [10, 7, 9].

For the sake of determining the deformation distribution it is necessary to make records of the billet and the workpiece (Fig. 1) in the desired number within the zone of plastic deformation (Fig. 2).



a) *b)*

Figure 1 - Microstructure of AlMgSi0.5 alloy: a) Billet (50x); b) Workpiece (100x).

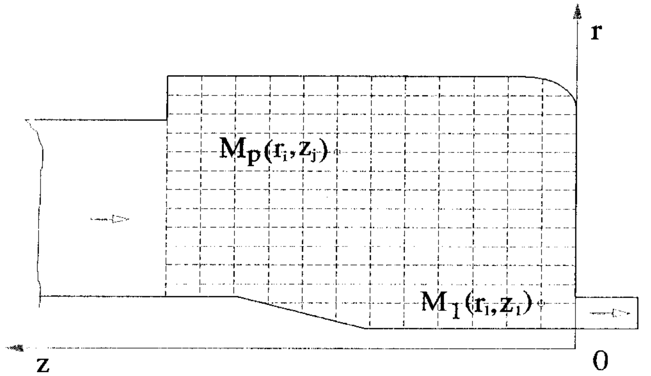


Figure 2 - Measurement Places Distribution in the Plastic Deformation Zone

Otherwise, the needed measurements can be directly made by the light microscope. A relatively complex calculation can be made easier by applying the MICROS program [9].

A part of the results of the calculation for the chosen technological parameters is given in Table 1.

Table 1. State of deformation for forward extrusion of hollow Al-profiles in bridge tool

TEHNILOGICAL PARAMETERS	
Extrusion material:	AlMgSi0.5
Profile/tool cipher:	ZP-KR / A-2-KR
Relative thickness of wall (or s_{max}/s_{min}):	0.135 (-)
Cross-section area of profile:	500.0 (mm^2)
Weight pro unit of profile lenght:	0.993 (kg/m)
Billet diameter/lenght:	220/820 (mm)
Natural (logarithmic) degree of deformation:	4.48 (-)
Initial billet/tool temperature:	495/460 (^{0}C)
Extrusion speed:	10.5 (m/min)

RESULTS OF COMPUTING										
p	i	j	ri	zj	φa	φb	φc	φe	vφ
1	1	1	5.00	3.00	-0.862	-1.137	1.996	2.005	-0.825
2	2	1	12.00	3.00	-0.529	-0.733	1.262	1.267	-0.795
---	---------		----------------		--------------------			-------	------
7	2	3	12.00	22.50	1.148	1.022	-2.170	2.171	0.924
---	---------		----------------		----------------------			-------	------
12	3	4	19.00	42.00	1.438	0.857	-2.294	2.319	0.689
---	---------		----------------		------------------------			------	------

On the basis of the known deformation state it is possible to apply different methods as well in order to determine the stress state in the plastic deformation zone [7], [8].

3. PROPERTIES OF THE EXTRUDED PROFILES

3.1. Profile Strength

Nowadays the manufacturers of profiles from Al-alloys offer to the market several hundreds of these products of diverse and complex geometric shapes. This fact confirms the above-made statement about a very diversified and wide application of Al-alloy profiles.

Since the Al-alloy profiles are also used as elements of light weight support structures satisfying carrying capacity (rigidity). This demand is, first of all, satisfied by choosing adequate dimensions and form of the profile's cross-section as well as by adequate strength of the material itself. For these applications the hollow profiles are most suitable.

The research done by a great many authors [5], [6] have shown that during the process of Al-profile extrusion the work hardening of the material is taking place. The illustration of this is given in Fig. 3 [11]. The results shown in Fig. 3 relate to the hollow profiles made of alloy AlMgSi0.5 (which is treated as a representative for Al-alloys suitable for hot extrusion).

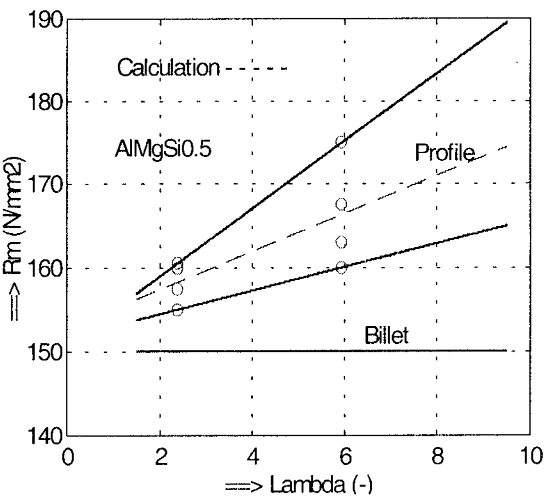


Figure 3 - Profile's Tensile Strength Dependence Upon the Conditional Extrusion Ratio

Tensile strength (as well as other indicators of the same kind) can be generally expressed in the form of the following function:

$$R_m = f\left(\varphi, \dot{\varphi}, T, \mu, H/2B, h/D\right) \tag{1}$$

where: φ - natural (logarithmic) degree of deformation (or reduction of the cross-section λ), $\dot{\varphi}$ strain rate (or extrusion speed V_e), T - billet temperature, $H/2B, h/D$ - geometrical parameters of die [11].

As a rule, the first four influential factors in equation (1) represent the most important factors of all metal forming processes. However, in extruding profiles from Al-alloys there is a set of peculiarities.

Firstly, the hollow profile extrusion is done in the regime of the so-called dry friction (without lubrication). This condition is necessary since the billet is first split upon the tool bridge and then it is again connected (welded) in the die chambers and, as compact continuum, it is extruded through openings (gaps) in the die. The lubricant presence would make the welding process considerably more difficult and unfavorably affect the extruded profile quality. In that sense, the tribological conditions are determined in advance.

Secondly, the temperature varying is limited to a narrow interval which is a consequence of the properties of the Al-alloys themselves. The varying of this factor in a narrow interval is unreliable (especially under manufacturing conditions) so that it is difficult to determine its qualitative and quantitative effect upon tensile strength.

For this reason, it the above-mentioned research [11], the other influential factors given in equation (1) remained varied in wide intervals. The experimental data processing has given a pseudo-linear dependence of tensile strength upon the mentioned influential factors [11]. Fig. 1 gives indicated limits of the extruded profiles' tensile strength interval for the given conditions as well as the tensile strength dependence upon the conditional extrusion ratio for average values of the other influential factors, that can be expressed by the following function:

$$R_m = 152{,}830 + 2{,}277 \cdot \lambda_s \tag{2}$$

The conditional extrusion ratio is defined with following relation [6], [11]:

$$\lambda_s = A_s / A_p \ (\lambda_s > 1) \tag{3}$$

where: A_S and A_P- cross-section areas of the workpiece in the material welding zone (in the die chambers) and of the extruded profile.

3.2. Seams on the Profile

The described Al-profile extrusion technology is also specific due to the fact that along the whole profile length there are two or more joints (seams) that can sometimes be seen with naked eye. The fact is that the seams on the profiles are an inevitable and unfavorable phenomenon at the same time, both from the aspect of carrying capacity (rigidity) of the profile and from the aesthetic perspective.

On the recorded microstructure (Fig. 4) it is easy to see the position of the seam while its width can be exactly enough measured by the microscope [11].

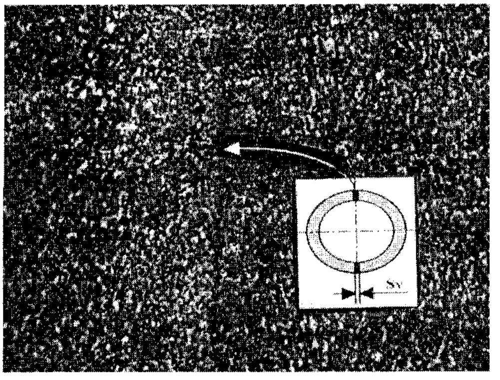


Figure 4 - Microstructure of the Extruded Profile from the AlMgSi0.5 *Alloy at the Junction (Seam) Place (100x)*

The research dealing with the emergence of seams upon profiles are carried out according to the above-described methodology. In that sense, the starting point was the logical assumption that the seam width depends upon the same influential factors stated in equation (1).

Experimental data and their analytical presentation are given in Fig. 5. For average values of the varied influential factors the linear function of the following form is obtained:

$$s_v = 37{,}595 - 1{,}947 \cdot \lambda_s \qquad (4)$$

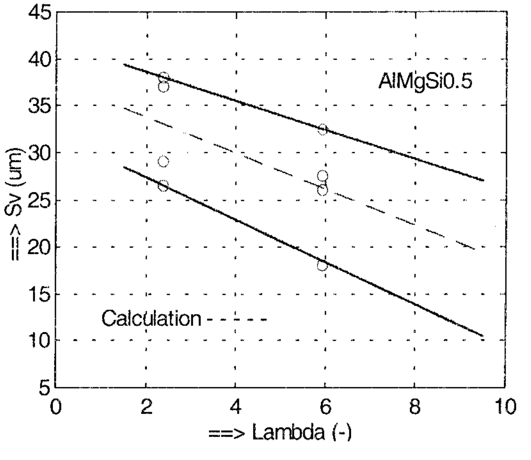


Figure 5 - Dependence of The Thickness of the Seam Welded on the Profile upon the Conditional Extrusion Ratio

3.3. Material Structure

The material microstructure recording can have many applications. As has been shown, on the basis of size and distribution of crystal grains the stress-strain state can be determined at particular points and then in the whole plastic deformation zone.

In the extrusion of hollow profiles from Al-alloys in the plastic deformation zone as well as in the extruded material there is prominent orientation of the crystal grains [12]. In the so-called "dead zones" in the die chambers crystal grains of great size are noticed. It is upon the grain size and orientation of the crystal structure that it is possible to observe the limits between the "dead zones" and the zones with intensive material flow. The difference in size of the crystal grains also provides for the determination of the welded joint (seam) width upon the extruded Al-alloy profiles.

4. CONCLUSION

The microstructural and mechanical examinations can help, to a considerable degree, the determination of optimal thermo-mechanic and geometric parameters of the Al-alloy profile extrusion process as well as the limit deformability of these materials.

The paper gives a special emphasis upon the effect of the deformation degree upon the extrusion process; likewise, it presents its positive effect upon the magnitude of tensile strength as well as width of the seams upon the extruded hollow profiles from Al-alloys.

5. ACKNOWLEDGMENT

The paper is a part of the research done within the project **SGR 4.05.0048.A**. The authors would like to thank to the Ministry for Science and Technological Development of Serbia for the financial support.

6. REFERENCES

[1] Conserva M.: Why Go for Aluminium Extrusions? ET 2000 Shaping the Future, Chicago, USA, 2000.

[2] Schütt J. H., Baumann H.: Leichtbau im Fahrwerk-Sektor. ATZ/MTZ,Sonderausgabe System Partner '97.

[3] Anon.: Für die Roslagsbahn in Stockholm: Neue Wagenkästen aus Aluminium. Schweiz. Aluminium Rundschau, No 4, 1989.

[4] Lugscheider E., Tillmann W.u.a.: Fertigung von Leichtbaustrukturen aus Aluminium-und Titan-Werkstoffen. VDI Berichte Nr.1080,1994.

[5] Spur G., Stöferle T.: Handbuch der Fertigungstechnik. Band 2/2-Umformen, Carl Hanser Verlag, München/ Wien, 1984.

[6] Rajtbarg L. H.: Proizvodstvo pressovanih profilej. "Metallurgija", Moskva, 1984.

[7] Smirnov-Aljaev G.A.: Soprotivlenie materialov plastičeskomu deformirovaniju, "Mašinostroenie", Leningradskoe otdelenie, 1978.

[8] Kolmogorov V. L.: Mehanika obrabotki metallov davleniem. "Metallurgija", Moskva, 1986.

[9] Marinković T., Marinković V.: Analysis of the deformation state of the hollow Al-profiles extrusion process by the microstructural method application. Journal for Technology of Plasticity, No 1/2, 2000.

[10] Storožev M. V., Popov E.A.: Teorija obrabotki metallov davleniem. "Mašinostroenie", Moskva, 1977.

[11] Marinković T. , Marinković V., Popović P.: Determination of tensile strenght of welded joint and width of tube obtained by process of extruding aluminium alloys in bridge tool. Journal for Technology of Plastcity, Vol. 20, No1/2, 1995.

[12] Claves S.R., Misiolek W.Z.et al: Effect of Die Design on Microstructure of Extruded Aluminium. ET 2000 Shaping the Future, Chicago, USA, 2000.