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TECHNOLOGICAL ASPECTS WHEN PERFORMING FRICTION WELDING OF HETEROGENOUS MATERIALS

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Keywords: roller, friction welding, heterogenous materials, diffusion, axial shortening, macrostructure, plastic flow, upsetting, cold-straining, crystalline modification.

1. ABSTRACT Compared with conventional procedures, friction welding is a non-electric joining procedure that has the following advantages: materials that are different both in their chemical composition and their melting points can be welded, as can materials having different dimensions and shapes; this is hygienic and highly productive procedure.

The issue of welding heterogenous materials - aluminum with stainless steel – must also be approached from the point of view of the fact that the aluminum surface is covered by an oxide film with totally different properties than those of aluminum. The paper presents the results of applied research, results obtained when performing a continuous friction welding of aluminum alloy-6060 rollers, with two 1.4104 or 1.4305 stainless steel rolls or St 37 with 1.4305 stainless steel rolls, as seen in figure 1.

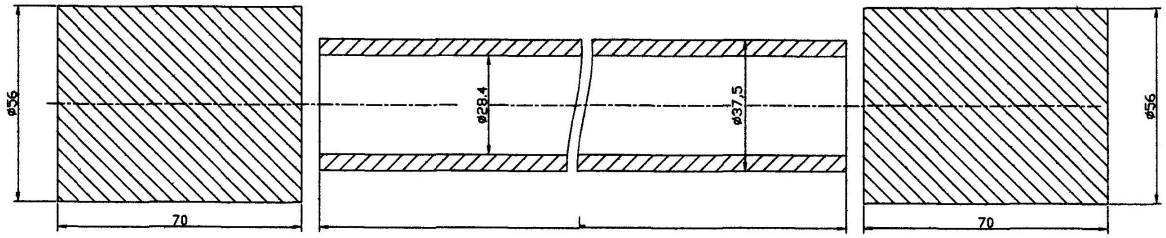
a ***b***

Fig. 1. Friction welded rollers : a - St 37 with 1.4305 steel; b- AlMgSi 0,7 F27 aluminum with 1.4104 steel.

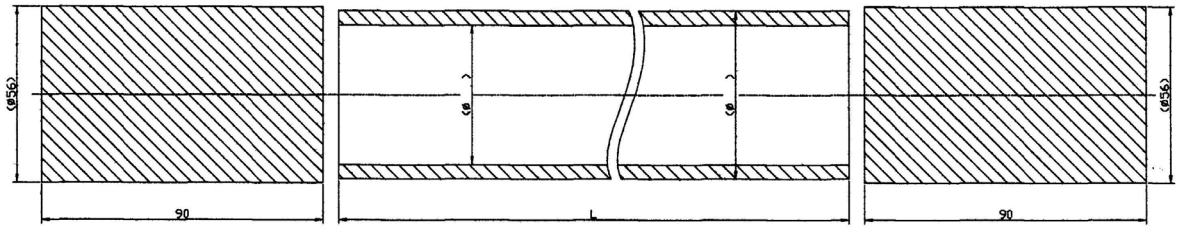
When performing continuous friction welding, the necessary heat is obtained by converting the friction mechanical energy between the elements that are to be joined into thermal energy, under a certain pressure.
The welding process takes place according to a work cycle specific to option a and option b in figure 1, respectively, cycles that include the following phases: fixing the components in the expander and the wedge grip of a special machine, pulling one of them into a rotation movement with constant or variable speed, pressing the other component with an axial force, heating up the contact surfaces until the plastic flow temperature is reached, braking and finally upsetting under zero speed.

2. INTRODUCTION

The rollers obtained by welding rolls made of 1.4305 or 1.4104 austenitic stainless steel with an intermediary cylindrical part made of AlMgSi 0,7 F27 aluminum alloy and St37 steel respectively, as in figure 2, are used in the printing industry, in order to help obtain high speeds when printing newspapers or books. The execution of these rollers stays between the tolerance limits admitted by DIN 2678m and DIN/ ISO1302. As for the shortening that takes place during the welding process, it is permitted to have a deviation from the **L** length of the intermediary (working) component, depending on its size.



a.



b.

Fig.2. Roller subassembly: a. Al 6060 with 1.4305 steel; b. ST 37 steel with 1.4305 steel

3. PRESENTING THE BASE MATERIALS

The materials that the rollers are made from are aluminum, non-alloy steel and stainless steel. The joining of materials with high heat conductivity, like aluminum and copper, is possible by friction welding and by creating cycles with high rotation speeds, associated with low welding times in order to decrease ZIT. Aluminum, which also has a low melting point and is protected (covered) by a thin oxide film (>0,1 microns) can be friction welded with a material that has high resistance, like stainless steel, in severe working conditions and with an intermediary cycle of: heating – friction – upsetting, placed between steel with steel and aluminum with aluminum respectively. The joining has properties comparable to those of the roller material.

Tables 1 and 2 present the chemical compositions of aluminum alloy – 6060, 6005/6105, according to EN AW or AlMgSi, according to ISO and of 1.4104 (X12CrMoS17/X14CrMoS17) and 1.4305 (10CrNiS18-9) stainless steel, while tables 3 and 4 show the mechanic features.

Table1. The chemical composition of the aluminum alloy - 6060,6005/6105

Chemical Comp. / Brand	Al [%]	Cu [%]	Fe [%]	Si [%]	Zn [%]	Ti [%]	Mg [%]	Mn [%]	Cr [%]
6005	Remainder	<0,1	< 0,35	0,6-1,0	<0,10	<0,10	0,4-0,6	<0,10	<0,10
6105	Remainder	<0,1	< 0,35	0,6-0,9	<0,10	<0,10	0,45-0,8	<0,15	<0,10
6060	98,0	0,1	0,2	0,45	0,15	0,1	0,45	0,1	0,05

Table 2. The chemical composition of stainless steel.

Chemical comp. / Brand	*Cr* [%]	*Ni* [%]	*C* [%]	*Si* [%]	*P* [%]	S [%]	*Mn* [%]	*Mo* [%]	*Cu* [%]	*N* [%]
1.4104	*15.5-17,5*	*-*	*0,10-0,17*	*Max. 1,0*	*Max. 0,06*	*0,15-0,35*	*Max. 1,5o*	*0,20-0,80*	*-*	*-*
1.4305	*17,0-19,0*	*8,0-10,0*	*Max. 0,10*	*Max. 0,10*	*Max. 0045*	*0,15-0,35*	*Max. 0,20*	*-*	*Max. 0,10*	

Table 3. Mechanical features of the aluminum alloy-6060

Features / Temperature/ Brand	Rp_{02} [N/mm^2]	R_m [N/mm^2]	A_5 Extension [%]	Hardness [Vickers]	A_{50} Extension [%]
0/6060	100	50	27	25	26
T_1/6060	150	90	25	45	24
T_4/6060	130-160	60-90	15-20	55	20
T_5/6060	220	185	13	80	13
T_6/6060	245	195-215	10-13	90	12

Table 4. Mechanic features of 1.4305 steel.

Features Temperature/ Brand	Rp_{02} [N/mm^2]	R_m [N/mm^2]	A_5 Extension [%]	Hardness [Brinel]	Toughness KV [J/cm^2]
1.4305	235	390-590	-	150-220	200

4. PARAMETERS OF THE WELDING PROCESS

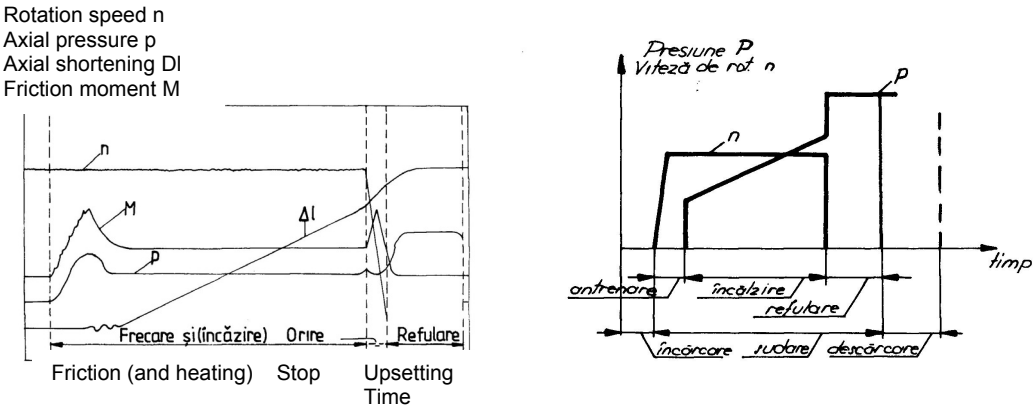
The process of welding by continuous friction takes place by a cycle having the following main phases: pulling a component in a rotation movement – the stainless steel part – with constant or variable speed, bringing into contact the other fixed component – the aluminum or St 37 roller, friction until the plastic deformation temperature is reached, upsetting the components so that they can be welded with a force $F_{ref.} > F_{frec}$.

The main parameters of the friction welding regime are: the rotation speed between the two components; the friction and upsetting pressure; the friction-upsetting-braking time; axial shortening.

The establishment of these parameters is determined by the nature of the welded materials, by the geometry of the joints and the quality of the surfaces that are brought into contact. The variation, in time, of these parameters is presented in figure 3 and the estimate values in table 5.

Table 5. Friction welding parameters

Parameters	d_n [mm]	$v_{relative}$ [m/s]	nxd_n rot.mm/ min]	$P_{fric.}Ol$ [N/mm^2]	$P_{fric.}Ol$ stain. steel [N/mm]	$P_{fric.}Al$ [N/mm]	$P_{ref./}$ $P_{fric.}$	$T_{fric.}$ [sec]	$T_{ref.}$ [sec]	$T_{inc.}$ [^{0}c]
Recom. Values	rated	0,6-3,0	(1,2-10)x 10^4	30-60	60-120	15-30	1,5-3,0	3,0-15,0	<2,0	400 - 600



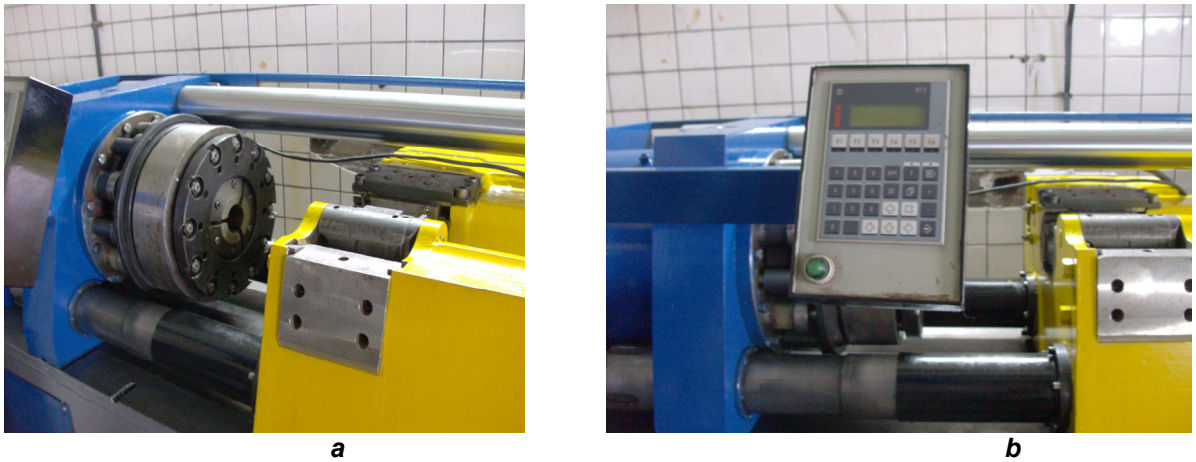
a ***b***

Fig. 3. The variation in time of the welding parameters: a – the welding cycle; b – detail for n and p.

5. EXPERIMENTS

5.1. MSF-40 Machine

Welding rollers made of aluminum alloy – 6060, 6005/6105 with 1.4305 stainless steel and of St 37 with 1.4305 stainless steel respectively, has been done on a machine of the type MSF-40, as seen in figure 4.



a ***b***

Fig. 4. MSF-40 Machine: a – expander – blade detail; b – panel for the command and adjustment of the welding parameters

The features of the MSF-40 machine are: maximum friction force of 400 kN; friction time of 0.1-99,9; upsetting and braking time of 0,1-9,9; expander rotating speed 2900 rot/min; maximum length of the components – 250 in the expander and unlimited in the wedge grip.

5.2 Preparing the samples and elaborating the welding technology
The friction welding parameters for heterogenous materials Al 6060 with 1.4305 steel and St 37 with 1.4305 steel respectively, have been determined and set experimentally, in correlation with the relations indicated in table 5 and are presented in table 6.

Table 6. The friction welding parameters

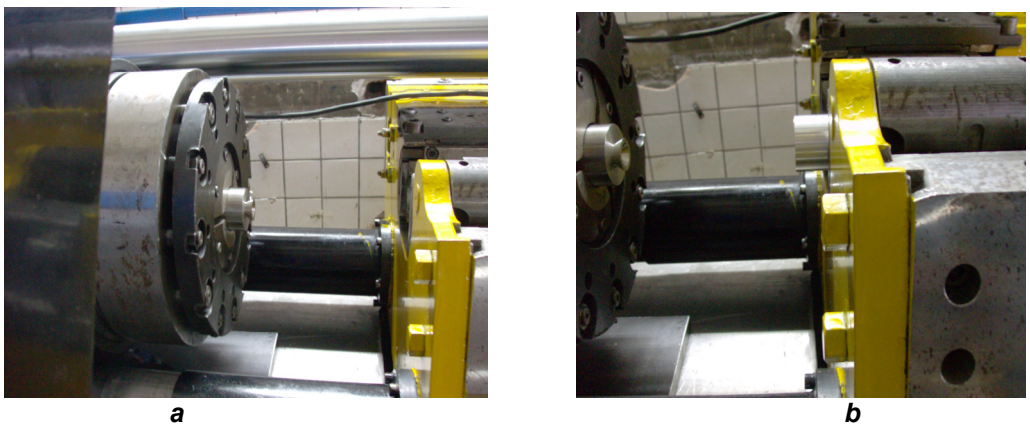
Parameters / Material	d_n mm	n rot/min	nxd_n rot.m/min.	$P_{fric.}$ Ol N/mm^2	$P_{fric.}$ Ol s. steel N/mm^2	$P_{fric.}$ Al. N/mm^2	$P_{ref./}P_{fric.}$	$T_{fric.}$ sec.	$T_{ref.}$ sec.	$T_{inc.}$ ^{0}c
Al 6060 S. steel 1.4305	50 56	2900	500	-	15	15	1,5	3,0	1,0	<500
St 37 S. steel 1.4305	54 56	2900	500	30	30	-	2,0	5,0	1,5	<600

The preparation of the components for welding is done by mechanical processing and is executed depending on the nature of the welded materials. Figure 5 shows the different ways of sample preparation.

a ***b***

Fig. 5. Preparation of the samples: a – detail stainless steel 1.4305; b - assembly Al 6060 roller and 1.4305 stainless steel.

The welding by continuous friction and the succession of the operations are presented in figure 6.



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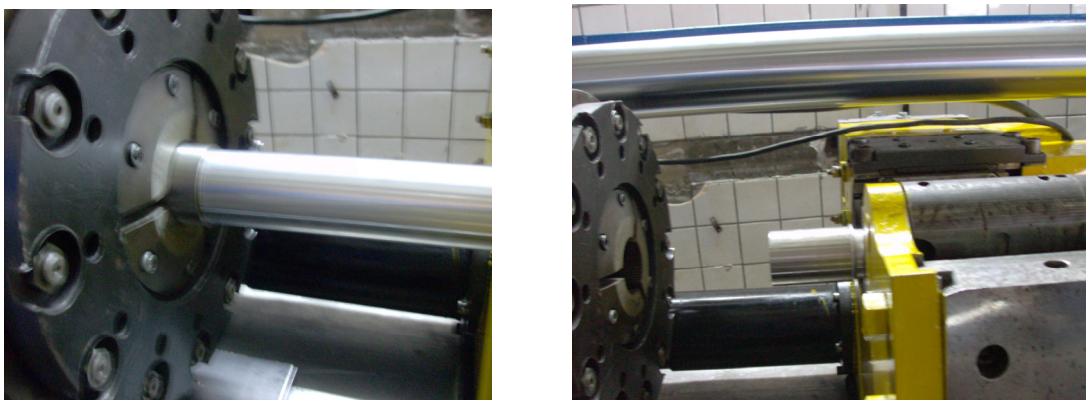


c ***d***

Fig. 6. Phases of friction welding: a – fixing in the expander; b – fixing in the wedge grip; c – approaching and friction; d – withdrawal of the welded roller.

The values of shortening when welding the rollers made of a 6060 aluminum alloy with 1.4305 stainless steel, depending on the length **L**, figure 2, are of: L_o=380,2-380,7; L_1=380,7-381,7; L_2=381,7-382,2; L_3=382,2-382,7; the shortening for St 37 steel with 1.4305 stainless steel is of: 831,,0-831,5; 831,5-832,5; 832,5-833,5; 833,5-834.

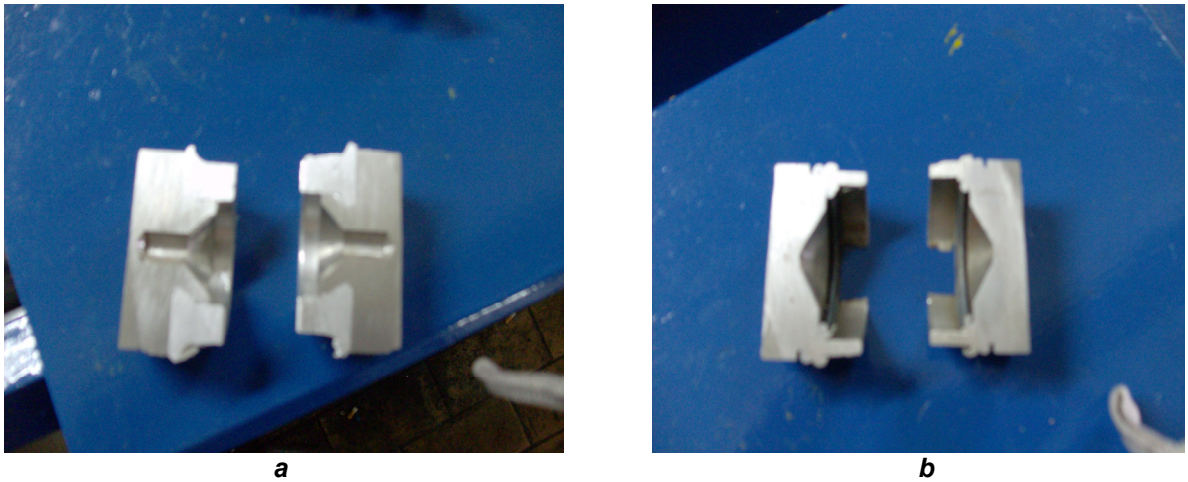
5.3. Experimental trials

The joining of aluminum alloy or St 37 steel bars – figure 7 – with cylindrical parts made of stainless steel 1.4305 has been done within the company S.C. TES Welding SA Timisoara, but only after the proper mechanical processing of the components made of 1.4305 steel.

a ***b***

Fig. 7. Friction welded samples: a – alloy of 6060 aluminum with1.4305 stainless steel; b - St37 steel with 1.4305 stainless steel.

The aspect of the joining as seen in a section of the welding axis is presented in figure 8.



a ***b***

Fig. 8. The macrostructure of the joining: a – alloy of 6060 aluminum – stainless steel 1.4305; b - St 37 hotel -1.4305 stainless steel.

6. CONCLUSIONS

Welding by continuous friction, with no additional material, is the process with most advantages in joining rollers made of aluminum alloy or non-alloy steel with stainless steel. The practical research done on a high number of samples led to the following conclusions:

- the joining of heterogenous materials made of 6060 aluminum alloy with 1.4305 stainless steel does not create problems when friction welding and neither does St 37 steel with the same stainless steel;
- maintaining the welding parameters constant leads to identical joinings;
- in order to join 6060 aluminum alloy with 1.4305 stainless steel, the welding is a mechanical combination found at the limit of diffusion – from the point of view of its resistance;
- the seam that results in the welding process can be removed by mechanical processing on the same machine.
- It is the process with the highest productivity and does not require operators with very special training.

7. BIBLIOGRAPHY

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