RESEARCH REGARDING THE FRICTION WELDING OF HETEROGENOUS MATERIALS

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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 be approached not only for the reasons we mentioned above but also because the aluminum surface is covered by an oxide film with totally different properties than those of aluminum. The paper presents the results of theoretical and 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.
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: 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. THE PHASES AND PARAMETERS OF THE WELDING PROCESS

2.1. Phases and phenomena characteristic to friction welding.
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 following phenomena appear during the welding process: a wearing of the contact surfaces; the forming and destruction of metallic links between the adjointed surfaces; rapid warming ups and sudden coolings of the microvolumes, under the condition of big pressures; plastic deformations of the knobs found on the contact surfaces; the cold-straining, crystalline modification, diffusion and reciprocal overlapping of the metal particles between components. The welding is a result of the fact that the particles slide between the two non-lubricated surfaces and of the transition, balance and then braking phenomena. The relative rotation speed has a linear variation from zero at the bars' axis to a maximum at their periphery. The friction moment and the axial movement speed of the plastified metal remain approximately constant, while in section they depend on the relative rotation speed and on the value of the axial force – figure 1.

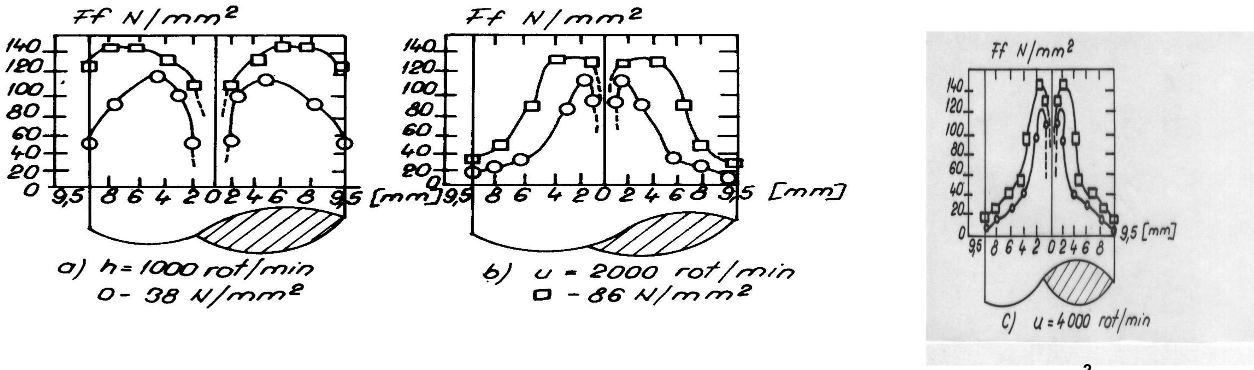
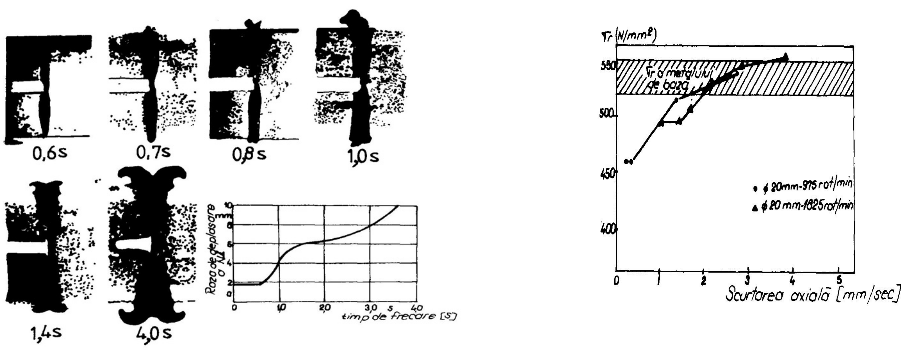


Fig. 1. The distribution of the friction force on section: a - n=1000 rot/min, p_{fr}=38 N/mm^2; b - n=2000 rot/min, p_{fr}=86 N/mm^2; c - n=4000 rot/min, p_{fr}=80 N/mm^2.

The movement of the plastified material to the ridge also depends on the slow-up value of the rotation speed on the moment of braking. Thus, a big slow-up – 2500 rad/sec^2 results in a small ridge, while a small slow-up - 10 rad/sec^2 results in a big ridge; these phenomena happen because of the plastified metal movement, which relates to its stabilization time – figure 2a. The movement of the plastified metal towards the ridge always starts in the rotating part.
The recommended speed is of 125 rad /sec^2 , until the speed lowers to about 250 rot./min., after which a sudden braking is ensured.



a ***b***

Fig. 2. Influences upon the form of the joining: a – of the friction – braking times; b – of the axial moving speed.

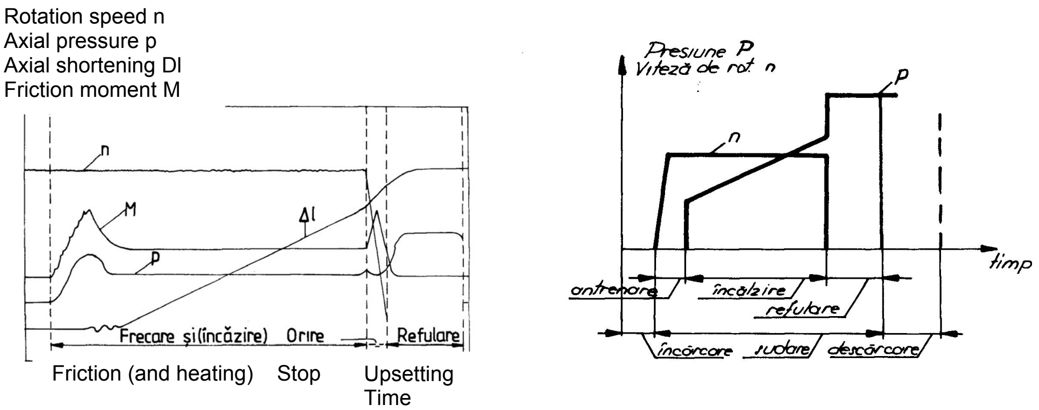
The mechanical features of the joining are close to the ones of the base materials and are only obtained once the conditions for the plastic deformation of the contact material are fulfilled and under a certain axial movement speed – figure 2b.

2.2. THE PARAMETERS OF THE FRICTION WELDING REGIME

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 1.

Table 1. Friction welding parameters

Parameters	d_n [mm]	$v_{relative}$ [m/s]	$n x d_n$ 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.

3. EXPERIMENTS

3.1. 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.

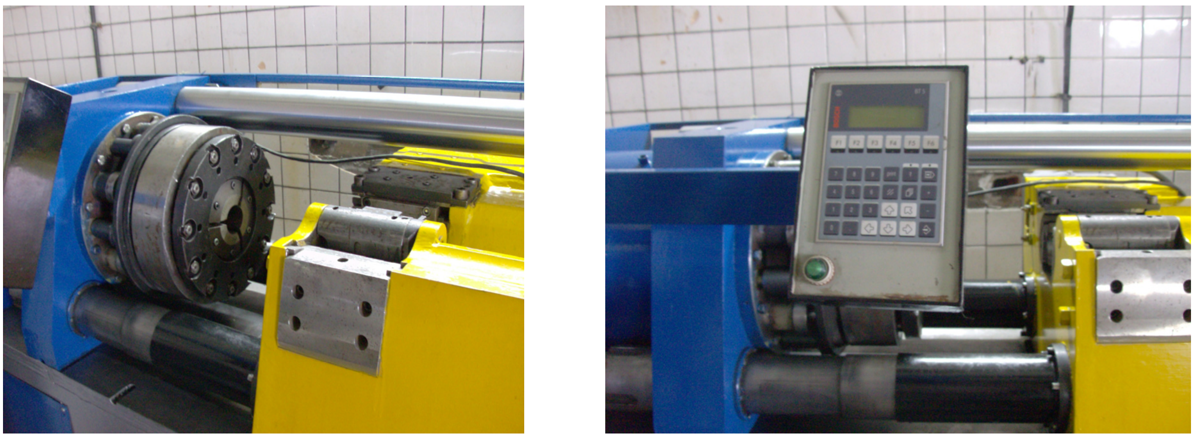


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Fig. 4. MSF-40 Machine: a – expander – blade detail; b – panel for the command and adjustment of the welding parameters

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.

3.2 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 1 and are presented in table 2.

Table 2. The friction welding parameters

Parameters / Material	d_n mm	n rot/min	nxd_n rot.mm / 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.	$T_{inc.}$ ^0c
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

3.3. Experimental trials

The joining of aluminum alloy or St 37 steel bars – figure 5 – 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.

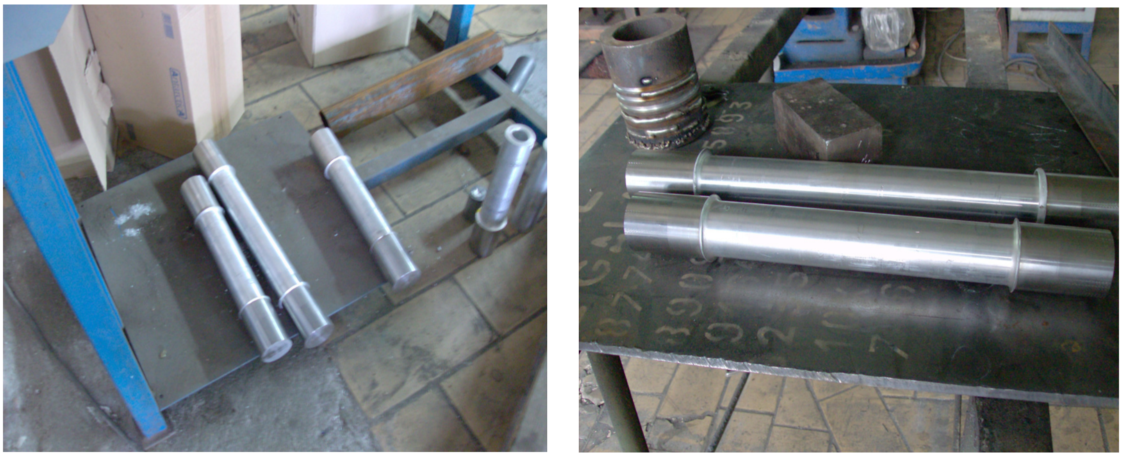

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Fig. 5. Friction welded samples: a – alloy of 6060 aluminum with1.4305 stainless steel; b - St37 steel with 1.4305 stainless steel.

The aspect of the joining as seen in a section of the welding axis is presented in figure 6.

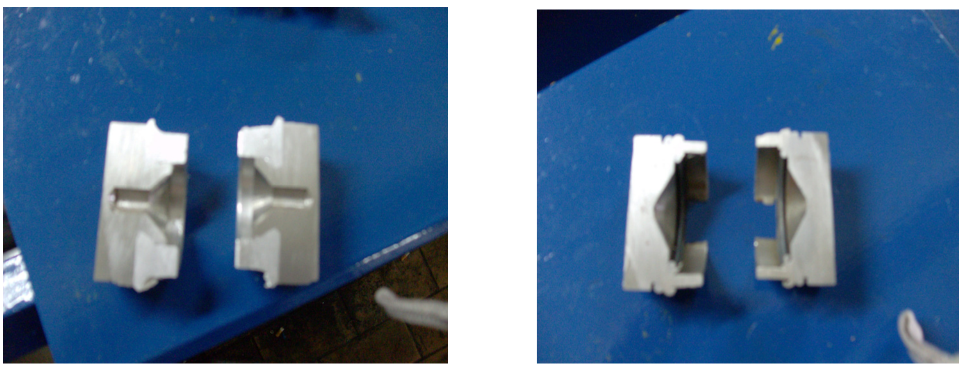

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Fig. 6. The macrostructure of the joining: a – alloy of 6060 aluminum – stainless steel 1.4305; b - St 37 hotel -1.4305 stainless steel.

4. CONCLUSIONS

Welding by continuous friction, with no additional material, is the process with most advantages in joining rollers made of heterogenous materials. 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.

5. BIBLIOGRAPHY

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