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Study of weldability in junction of dissimilar materials using the welding process by conventional rotary friction – FW

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Abstract. The objective of this project is to study the behavior of weldability, heat affected zone and thermal conductivity of the solid state junctions for various applications. The joints will be obtained through the conventional rotary friction (FW) process, combining the heat generated through the friction of two surfaces and bonding by hot forging, produced at temperatures lower than the melting temperature of the base materials. The results will be analyzed through mechanical stress tests such as tensile, compression, folding, Vickers microhardness, Charpy impact and metallographic. The strength of the joint will be analyzed given some input variables such as: friction time, forging pressure and speed of rotation.

Keywords. *Weldability, Friction Welding, Solid State Junctions, Dissimilar Materials.*

Introduction. The union of solid state materials through friction welding has been a challenge for Brazilian engineering, given the low literature, low dissemination and high values of the equipment, limiting studies, research and production to countries that have technological advances in automation.

Considered one of the greatest technological innovations in the field of welding since its discovery until today, the process of welding by friction brings together numerous advantages that attract research and development in this area. Some modalities would be impractical or even impossible to weld, which make this process, as well as promising, usable in several branches of mechanics. The process also attracts attractive to the conventional system having as main characteristic the fact that the junction still occurs in a solid state, below the melting temperature of the materials involved. Because they do not use an electric arc, friction welds do not produce fumes, sparks, smoke, radiation, electrical problems involving high voltage, elements that are highly detrimental to the health of the operator, do not generate localized fusion, porosity and losses in mechanical properties, besides the resistance of the weld. Although this welding process is well known in several countries, in Brazil it still comes down to few applications related to the automotive industry. Therefore, there are innumerous reasons why, increasingly, incentives, studies and research are being shifted to this branch of mechanical science that can still contribute to the development of the national industrial.

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Main text. The process of welding by friction is a widespread process and has been used more widely after the second major war by the Soviets who, in 1956, patented and deposited their credits with Chudikov (1). It is a process of bonding materials in the solid state, by obtaining coalescence of metals and non-metals, by means of heating with or without the use of pressure and / or addition material, according to the American Welding Society (2) classification, where the bonding between these occurs at temperatures below the melting temperature of the materials involved (3). There are a number of authors who consider that the presence of a film of molten material between the rubbed faces may occur (WICHELHAUS, 1975 quoted by MEYER, 2002). Although we have this line of authors, the analysis of the structure of the welded joint does not show the occurrence of union formed by the hot work to which the piece was submitted, leading to the evidence that there was no melting of material (4). The union occurs by the heat generated by the conversion of mechanical energy into thermal at the interface of the materials without the application of electric energy or external heat source. This heating is due to the friction generated on the surface of the materials, where one of the parts is rotated and held under pressure against the other, which is fixed as shown in Figure 1(5).

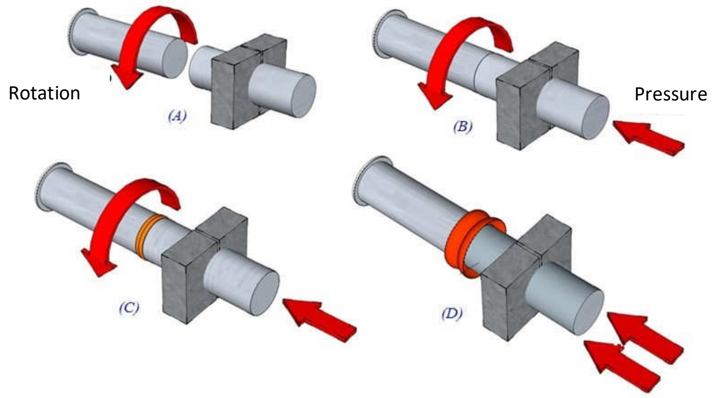

Figure 1. - Inertial friction welding steps.

The variants of the process of welding by friction are denominated as Conventional or by Continuous Drag and by Inertia (6). The present work will focus on Continuous Drag Welding.

Conventional or continuous drag welding

The parts are fixed in the machine and one of them is accelerated until reaching the appropriate speed, by means of a motor unit, according to Figure 2. The piece that is stopped is displaced by an axial force until touching the rotating piece. This contact causes the surfaces to heat by friction. When the contacting surfaces reach the forging temperature of the materials, the drive unit is disengaged from the rotating part, it is stopped and the axial force is increased for forging. This force is maintained until the parts cool and are welded (7).

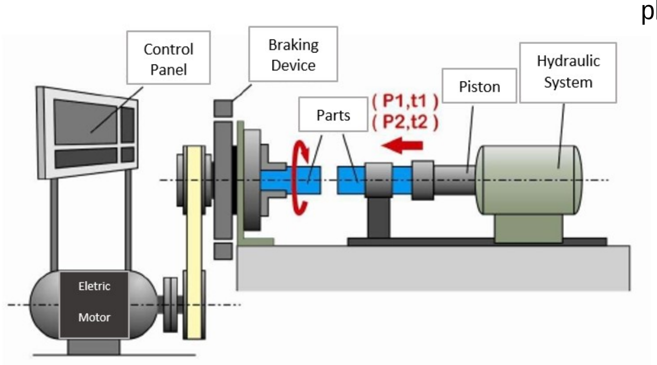

Figure 2. - Conventional friction welding.

Phases of the process

The process of welding by friction can be separated in different phases and this division varies according to the author. This can be divided into two, three, four and up to five phases. The four-phase division is used by most of the authors and seems to be the most adequate to be presented in this project, and includes: friction phase, heating, deceleration and union (8).

Parameters of conventional friction welding or continuous drag

The main parameters of process control are: rotation speed, burn off length, axial force applied and heating time. The combination of these factors directly influences the final quality of the weld so that microstructural embrittlement does not occur, as well as lack of adhesion between the two bodies, as well as other possible defects in this process (9).

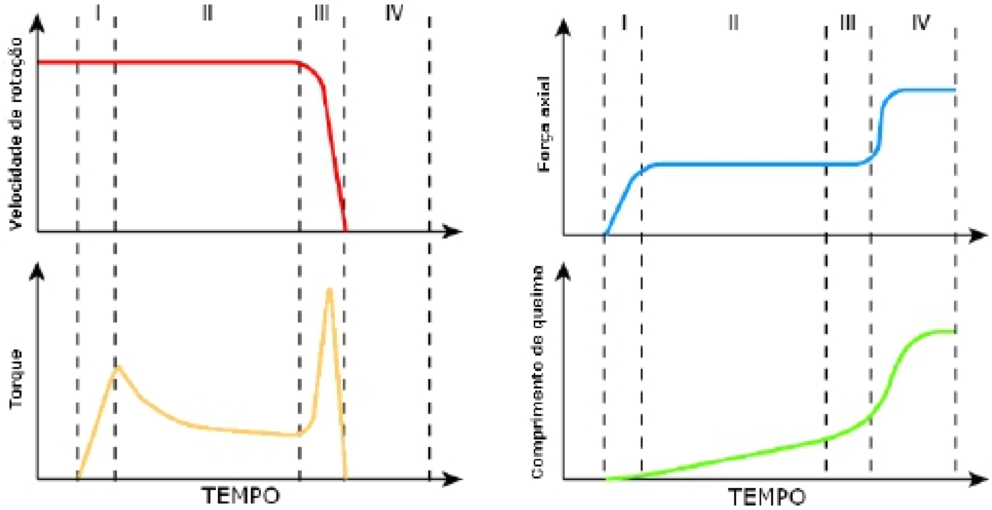

Figure 3. - Schematic illustration of the parameters during the process of welding by friction by the conventional method (I: Friction, II: Heating, III: Deceleration, IV: Union). Adapted MEYER, A. Friction Hydro Pillar Processing.

Advantages and disadvantages

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Advantages: self-cleaning process, no need for addition metal, flow and / or protective gas; absence of defects related to solidification phenomena, low amount of energy transferred to the part, formation of a narrow ZAC; possibility of joining dissimilar metals, it can be automated and operated at long distances, it allows the realization of welding in explosive atmosphere, without risk of explosion, low costs, in most cases, the resistance of the weld is equal to or even higher than of base metals.

Disadvantages: at least one of the parts must have an axis of rotation, internal burr in tubes, limited to top, flat and fillet welds, need a system with high rigidity and fixation and high initial cost with equipment and tools.

Copper

Copper is a chemical element of symbol Cu (from the Latin cuprum), atomic number 29 (29 protons and 29 electrons) and atomic mass 63.57 u, and valencies +1 and +2. At room temperature the copper is in the solid state. Classified as transition metal, it belongs to group 11 (1B) of the Periodic Classification of Elements. It is one of the most important metals industrially, of reddish color, ductile, malleable and good conductor of electricity. Known since prehistory, copper is currently used for the production of electrically conductive materials (wires and cables), and in metal alloys such as brass and bronze. It is nowadays obtained through ores, with sulphurates being the most widely used - chalcopyrite ($Cu2S + Fe2S3$ with 34.5% copper) and calcosite ($Cu2S$ with 80% copper). It is not magnetic and can be used pure or in alloys with other metals which give it excellent chemical and physical properties.

Copper and its alloys

Copper is usually used in its pure form, but can also be combined with other metals to produce a huge variety of alloys. Each element added to copper allows to obtain alloys with different characteristics such as: increased hardness, resistance to corrosion, mechanical resistance, machinability or even to obtain a special color to match certain applications. There are several types of copper alloy. Copper alloys exhibit excellent ductility both hot and cold, albeit somewhat inferior to pure metal. The main copper alloys are: commercially pure copper; brass; bronzes; copper-nickel alloys (10).

The proposal of this project is based on the use of the workable copper alloys, having its designations given by Metals and Alloys ASTM (11).

The Crystalline Structure and the Plastic Deformation of Copper

Having crystalline structure of face centered, the copper is a metal of great ductility. Unlike aluminum, also with face-centered structure, copper is very sensitive to the formation of mechanical maclas and annealing. It is assumed that the high plasticity of copper is due to the possibility of deforming at the same time by maclation and slip in relation to the aluminum that deforms almost exclusively by slipping. During heat treatments, the growth of copper grains is less pronounced than in aluminum; assuming, too, that the maclas are responsible. The appearance of annealing mats in copper limits grain growth. For the same reason, it is difficult to

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prepare copper monocrystals, except for controlling the cooling during solidification, that is, large crystals can not be made by recrystallization as in the case of aluminum.

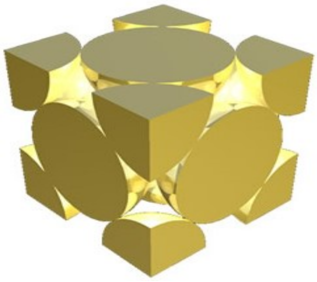

Figure 4. - Structure of copper - cubic face centered

Mechanical Properties of Copper

Having a modulus of elasticity between 110 and 125 GPa, its main mechanical properties are in the table below: (12).

Table 1. mechanical properties of pure copper.

Condition	Conformed	Hot Rolling	Ruffled
Tensile strength, Kg/mm^2	15	22 a 24	40 a 50
Yield strength 0,2%, Kg/mm^2		7	35 a 45
Elongation in 50mm, %	25	45 a 60	4 a 5
Stricture, %	Até 75	40 a 60	2 a 3
Brinell Hardness, Kg/mm^2	40	40	98
Fatigue Limit, Kg/mm^2		7	14

Materials

In this proposal we will used, the UNS C 64700-C66100 copper alloys in the shape of a cylindrical bar with 19.0 mm and 6000 mm in length, having their nominal chemical compositions and mechanical properties presented in the tables below

Expected results

Through the conventional rotary friction welding process and the study of the mechanical and metallurgical properties found after the tests carried out and with the support of studies presented in a large literature, the following results are expected:

i. Efficiency in soldering of dissimilar materials using copper alloys;

ii. Interdiffusion between the main chemical elements that make up the alloy as Si, characterizing diffusion as the main mechanism of bonding in the friction welding process as reported by Zepeda (3) and others;

iii. During the welding, a great deformation of the alloy of lesser hardness occurs.

iv. Emergence of burrs and reduction in length of specimens due to plastic deformation;

v. Different values of Vickers microhardness both in the central region and in the ends according to the reference of the alloy used;

vi. Obtain temperatures at the connection interface near the hot forging range of the alloy;

vii. Obtain ideal parameters of P1, t1, P2, t2 for the equipment used in order to establish the most efficient and fast way for the welding process;

viii. Obtain higher heating ranges in the initial phase of the welding until there is stabilization due to the deformation and plastic flow of the alloy;

ix. Understand and understand the main characteristics of the friction welding process, the mechanism of bonding between various alloys and the feasibility of this application in the production process in the main industrial sectors.

Conclusion. Through the literature review it is clear that the friction welding process is a significant alternative for joining dissimilar joints, which in traditional or more commonly used processes would become extremely difficult or impossible to perform. This possibility allows materials with no molecular affinity to unite and coexist each with its own characteristics and functions. Although very little studied and applied only to specific cases, the field is vast so that studies and possibilities can be expanded, creating unions with infinite series of materials, adding knowledge to industry and research. Like all other welding processes, friction welding has its restrictions, which in no way relegates this form to the background and does not undermine its importance. Studies oriented to mechanical properties, thermal conductivity and welding energy can be deepened bringing important conclusions on the subject.

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Disclosure. The authors report no conflicts of interest in this work.

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