

# PHYSICAL AND METALLURGIC CHANGES DURING THE FRICTION WELDING OF HIGH-SPEED CUTTING STEEL AND TEMPERED STEEL

*Nada Ratković, Aleksandar Sedmak, Milorad Jovanović, Vukić Lazić, Ružica Nikolić, Božidar Krstić*

Original scientific paper

This paper outlines the basic principles of welding by friction of high-speed cutting steel and tempered steel from the viewpoint of metallurgic processes that are going on in the material. The bases of welding by friction of different materials are outlined in a theoretical way. The experimental part of the paper also relates to friction welding of samples made of different metals: high-speed cutting steel (HS 6-5-2-5) on one hand and the tempered steel (C60) on the other.

**Key words:** friction welding, base metal, friction phases, diffusion, joint line, friction time

## Fizikalne i metalurške promjene tijekom zavarivanja trenjem brzoreznog i kaljenog čelika

Izvorni znanstveni članak

Ovaj rad daje osnovne principe zavarivanja trenjem brzoreznog čelika i kaljenog čelika s motrišta metalurškog procesa koji se odvija u materijalu. Osnove zavarivanja trenjem različitih materijala navedene su teorijski. Eksperimentalni dio rada odnosi se na zavarivanje trenjem uzoraka izrađenih od različitih metala: brzoreznog čelika (HS 6-5-2-5) s jedne i kaljenog čelika (C60) s druge strane.

**Ključne riječi:** zavarivanje trenjem, osnovni metal, faze trenja, difuzija, linija šava, vrijeme trenja

### 1

#### Uvod

#### Introduction

Friction welding falls under procedures of joining metals in solid state. The joint is realized by action of a pressure force on contact area, converted into plastic state. Concentrated separation of friction heat and plastic deformation of joints next to the line of contact are the basis of friction welding process. Physical essence of this process is based on transformation of mechanical into thermal energy.

One of the first applications of welding was manufacturing of cutting tools, in a way that high-speed cutting steel and tempered steel were mutually welded. Resistance properties of these steels significantly differ in hot state, because during the hot face contact a certain penetration of high-speed cutting steel into tempered steel occurs. Their thermo-physical properties also differ. Therefore it is necessary to determine welding parameters so as to overcome great differences in thermal stability of these two steels.

### 2

#### Basic phases of friction welding process

#### Osnovne faze procesa zavarivanja trenjem

During the friction welding with continuous drive, energy gets released in the friction area by rotation of one welded part while the other welded part stands still. Adhesion joints are formed in the most protuberant points of contact by molecular and mechanical action on contact surfaces at the very beginning of the process. Adhesion bonds are stronger than the base metal so shearing will occur at the small distance from the contact surface; then comes the separation and transfer of particles from one base metal to the other.

Friction welding process consists of the following phases (Figure 1):

- 1 Establishing of contact
- 2 Phase of the initial instable friction

- 3 Phase of stable friction

- 4 Phase of braking and compression.

The initial friction phase occurs at the very beginning of the friction process and lasts until the friction force reaches the first maximum. Occurrence of the first maximum can be explained by hydrodynamic phenomena in the contact layer. By interaction of metal particles, which rotate at the speed that is approximately equal to the half of angular speed of the welded parts, the hydrodynamic lubrication occurs, accompanied by the maximum friction moment.

Particles of both base metals get mixed in the second phase. In a very narrow area, several micrometers wide, in the area of increased temperatures, the diffusion redistribution of particular alloying elements occurs. Significant plastic deformation can occur in this phase on both base metals because they become softened at high temperature.

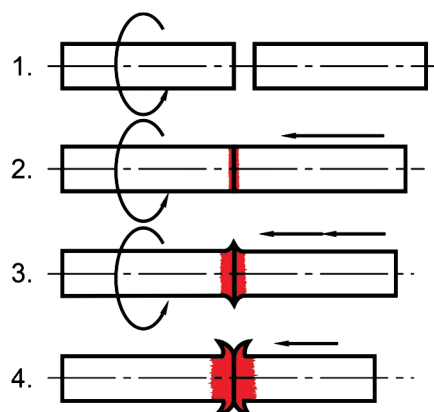


Figure 1 Basic phases of friction welding process  
Slika 1. Osnovne faze procesa zavarivanja trenjem

The order of magnitude of the second phase duration ranges from several tenths of a second to several seconds, which depends on base metal properties and welding mode. This phase is regarded as complete when the process reaches the quasi-steady state. Then follows the third phase









