THE ROLE OF AXIAL PRESSURE FOR FRICTION WELDING OF QT HEAT TREATED COMPONENTS

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Abstract: In this paper is analised the effect of axial pressure on modification of heating and cooling conditions of alloyed steels for quenching and tempering. By sclerometric tests correlated with cold bending, toughness tests and metallographic investigations, particularities of martensitic transformations in the joint plane are justified, with corresponding consequences on fragility on the welded joint.

1. Introduction

In this moment there are enough results concerning friction weldability of QT steel components. A lot of research papers, including some from our country, presents useful results for thermal field developed, mechanical and microstructural characteristics of welded joints, fracture mechanics tests, etc. [4].

Because of this, the paper will renounce to a detailed approach to process particularities of obtaining a friction welded joint by QT steels. Although, to evaluate characteristics of the dissimilar joints made from different materials, thermal treatments and thermo-chemical treatments were necessary researches to obtain dissimilar welded joints from QT components, using different axial pressure values. Results can be compared directly with those from similar welded joints from nitrided components or with those between a QT component and a nitrided component.

2. Experimental results

The first experimental tests revealed that friction welding of heat treated or thermochemical treated components needs relatively high values of axial pressure. Modification of axial pressure values determines changes of the heating and cooling conditions, aspect that can be seen on hardness curves in central zone and marginal zone of the welded joint. Directions of hardness tests are presented in figure 1 and results are presented in figure 2.

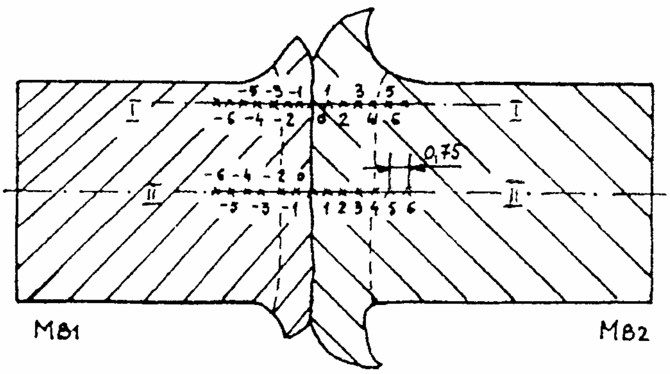
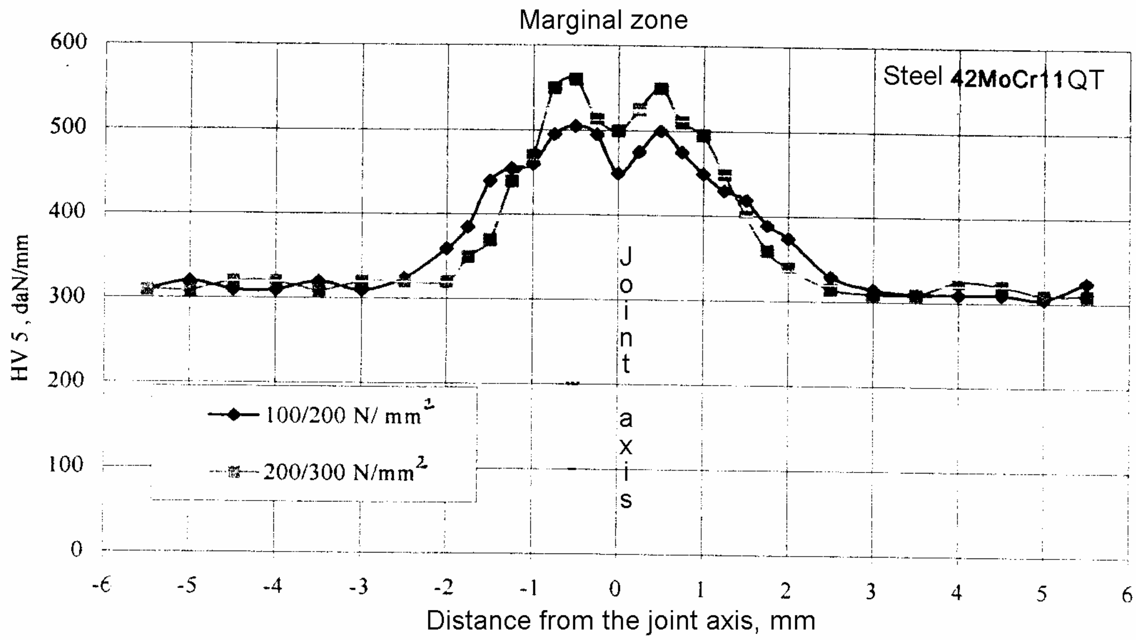


Fig. 1 Vickers hardness imprints distribution.

In case of pressure levels of 100/200N/mm^2, HV=450-500daN/mm^2 are obtained and as long as axial pressure increases hardness increases significantly up to HV=500-570daN/mm^2.

The phenomenon can be explained by the fact that the increase of friction pressure determines the plasticization of the material from the contact zone in a shorter time and it's expulsion into the flash. This will diminish conduction in axial direction; HAZ will become less extended and thermal gradient steeper. In the same time, radial thermal conduction along axial direction of the sample will be lower. HAZ became a bi-concave shape when friction pressure increases (figure 3). This can lead to initiation of cracks in central zone of the sample when the upset pressure would increase significantly compared to friction pressure, because deformations will take place in colder materials, which is less deformable.



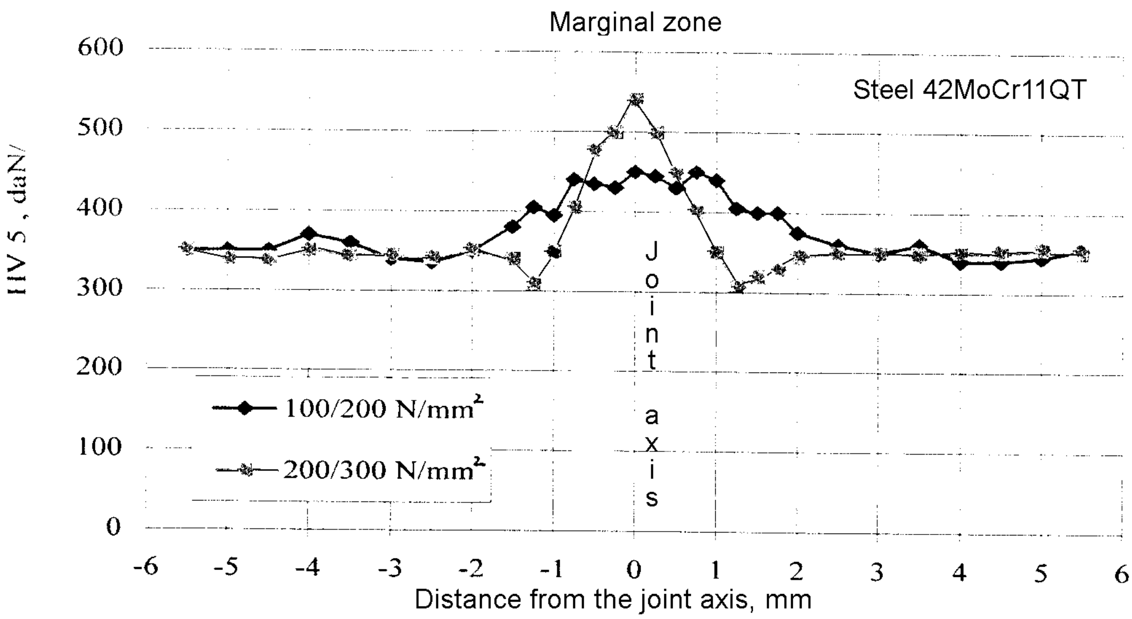
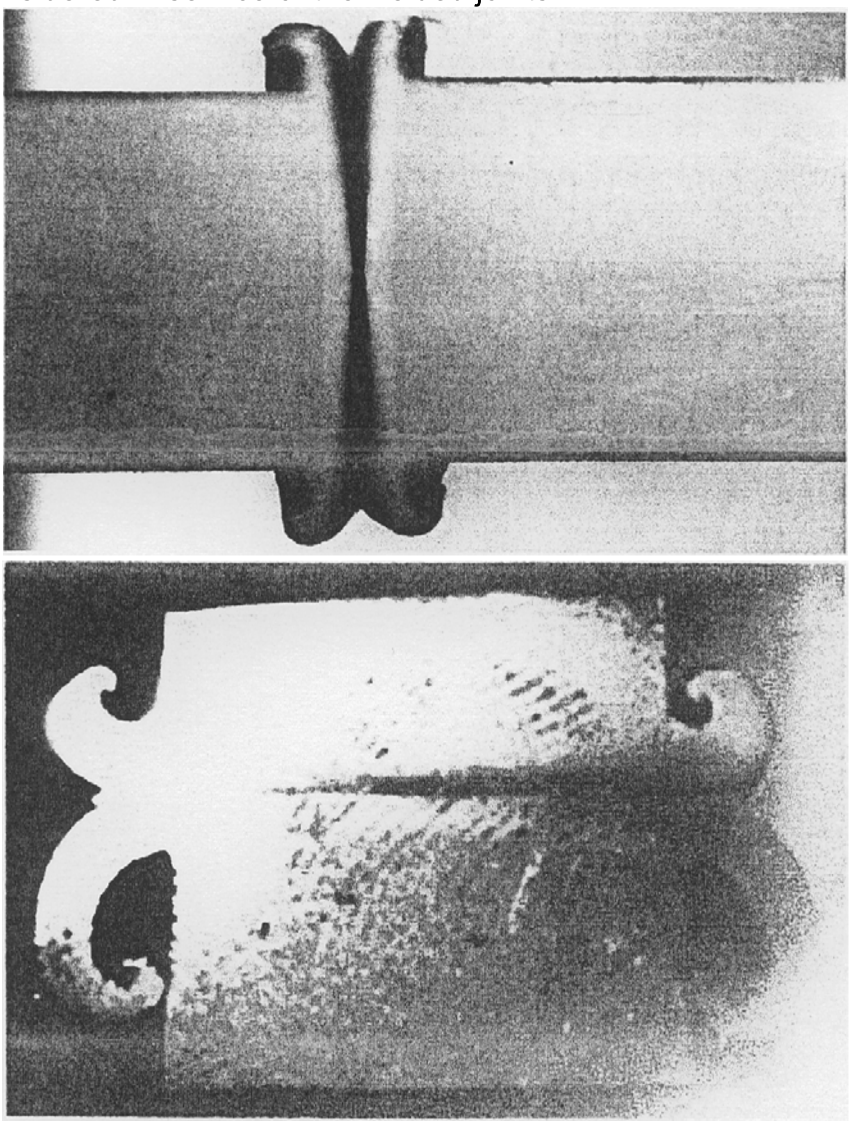


Fig. 2 Hardness gradient of 42MoCr11 welded joints for two axial pressure levels: a – in marginal zone; b – in central zone.

In the joining plane from central zone of the welded samples appears a hardness peak and its numerical value is higher when axial pressure increases. Against this fact, hardness in marginal zone should decrease because heat accumulated in the over heated flash is transmitted to the near material and so takes place a decrease of the cooling speed, this take place only to non-alloyed steels that have a relatively high critical hardening speed.

Tested steel has an enough high hardenability, respectively a relatively low critical hardening speed and as a result will have an increased sensitivity to hard and fragile constituents formation like bainite and martensite in the welded joint.

Also due to the heat developed during the welding process, at a certain distance from the joint plane, appears a decrease of hardness (figure 2b) due to a tempering effect. In a narrow zone of material the temperature will be higher than tempering temperature of 600°C of the QT components, obvious in this region of the material austenitizing temperature will not be reached. Although hardness decrease is relatively low (30-40HV), it should be considered in service of the welded joints.



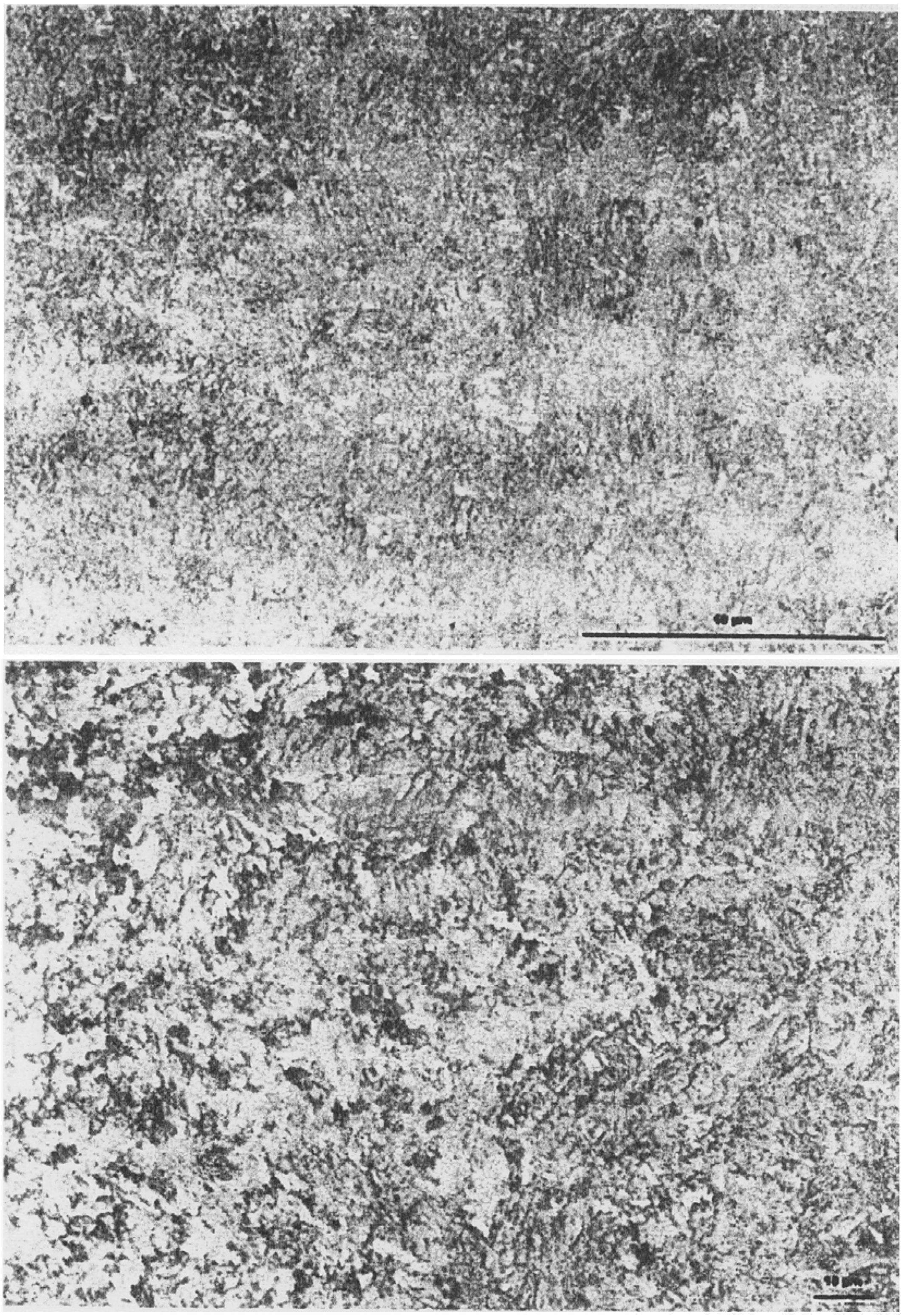
a

b

Fig. 3 The influence of axial pressure on 42MoCr11 welded joint macrostructure: a – axial pressure 100/200N/mm^2; b – axial pressure 200/300 N/mm^2.

As long as friction pressure increases, peak temperature reached in the joint plane increases and this leads to a high increase of the grain size.

Usually, comparing with base metal, friction welded joints have a finer grain structure because hot plastic deformation during welding is accompanied by a recrystallization of the material. Although, crystallization takes place, at high values of the pressure, grow of the grains can not be blocked. Even more, as a result of biconcave HAZ developed during upset with relatively low pressure, recrystallization in this domain will be less favoured.

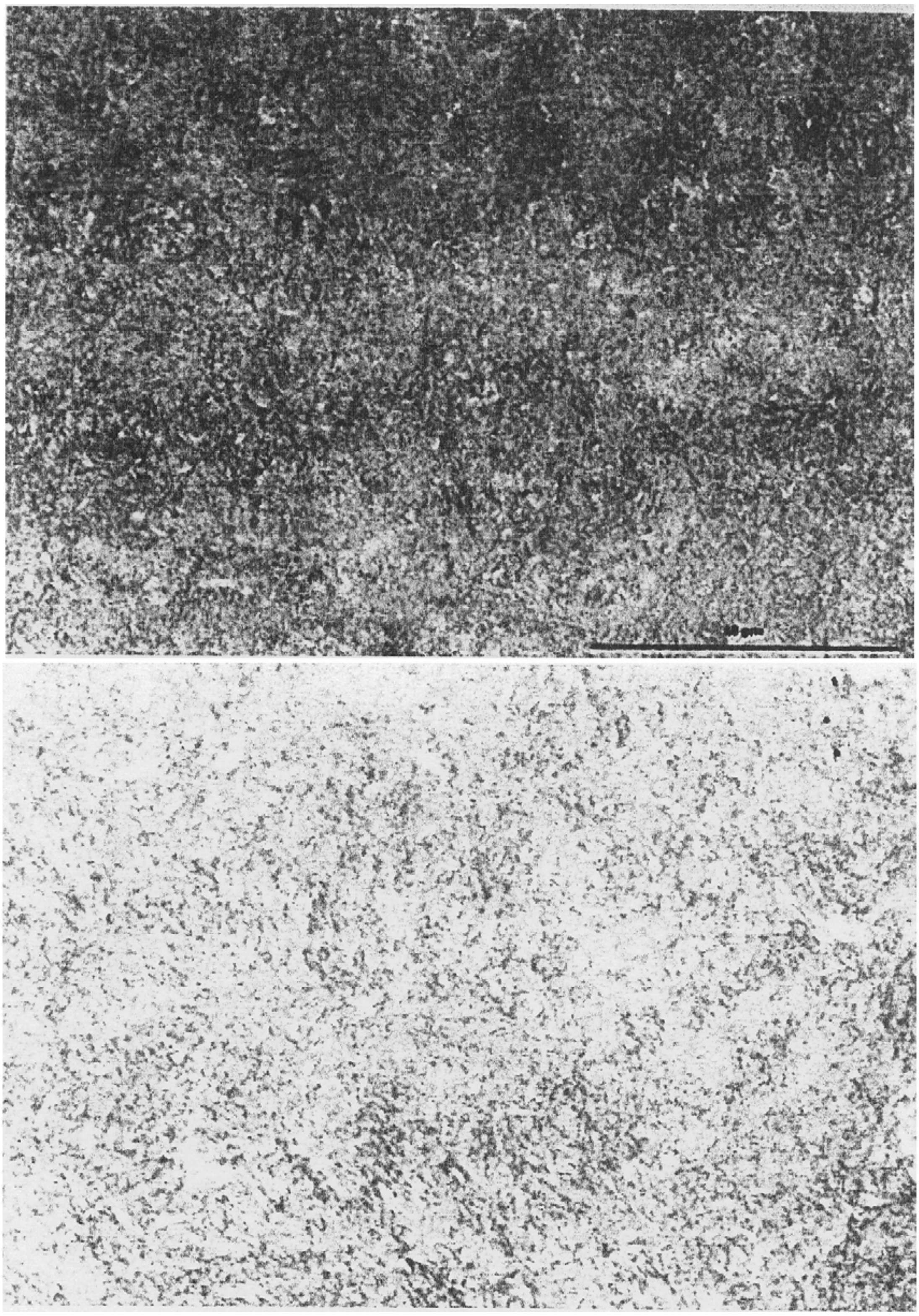


a

b

Fig. 4 Micrographic image of the central zone from the joint plane for high axial pressure.

High grain size determines a hardness increase because stability to transformation of the undercooled austenite in pearlitic domain will be increased. Against this, bainitic transformation will not be influenced significantly. Because in this region of the plasticized material from the centre of the sample, sub-cooling temperature of the austenite is higher than in close proximity zones, results that here will be formed superior bainite and martensite (figure 4) and in proximity zones mainly inferior bainite (figure 5).



a

b

Fig. 5 HAZ micrographic image from the central zone of the welded joint for high axial pressure.

42MoCr11 QT steel friction welded joints were tested to cold bending and toughness. Before testing the flash was removed by machining.

The results revealed that as high is the axial pressure values as low were the bending angle and fracture force (34°, 5200daN at pressures of 100/200N/mm^2, respectively 27°, 4300N/mm^2 at pressures of 200/300N/mm^2). Explanation of this modification consists of higher hardness in the joint zone and higher deviation of the deformed fibres, both generating a premature fracture of the material.

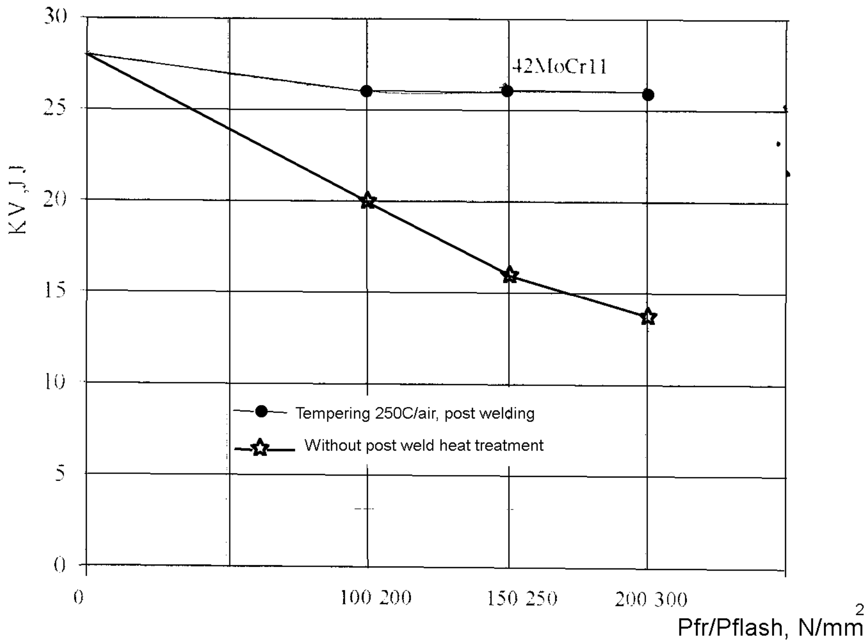


Fig. 6 Axial pressure on impact energy, KV.

Similar, the lowest values of fracture energy KV were obtained for samples welded with the highest values of axial pressure (figure 6).

Micrographic examination of samples tested to impact bending at room temperature revealed that fracture surfaces have a fragile behaviour (figure 7), that means the fracture takes place without perceptible plastic deformation.

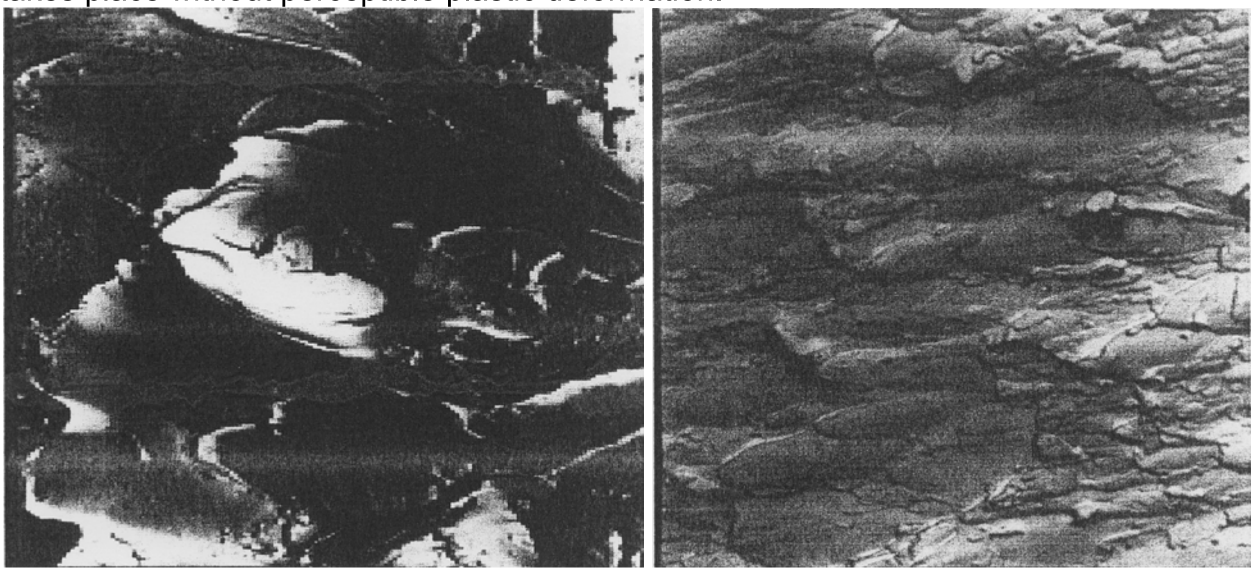
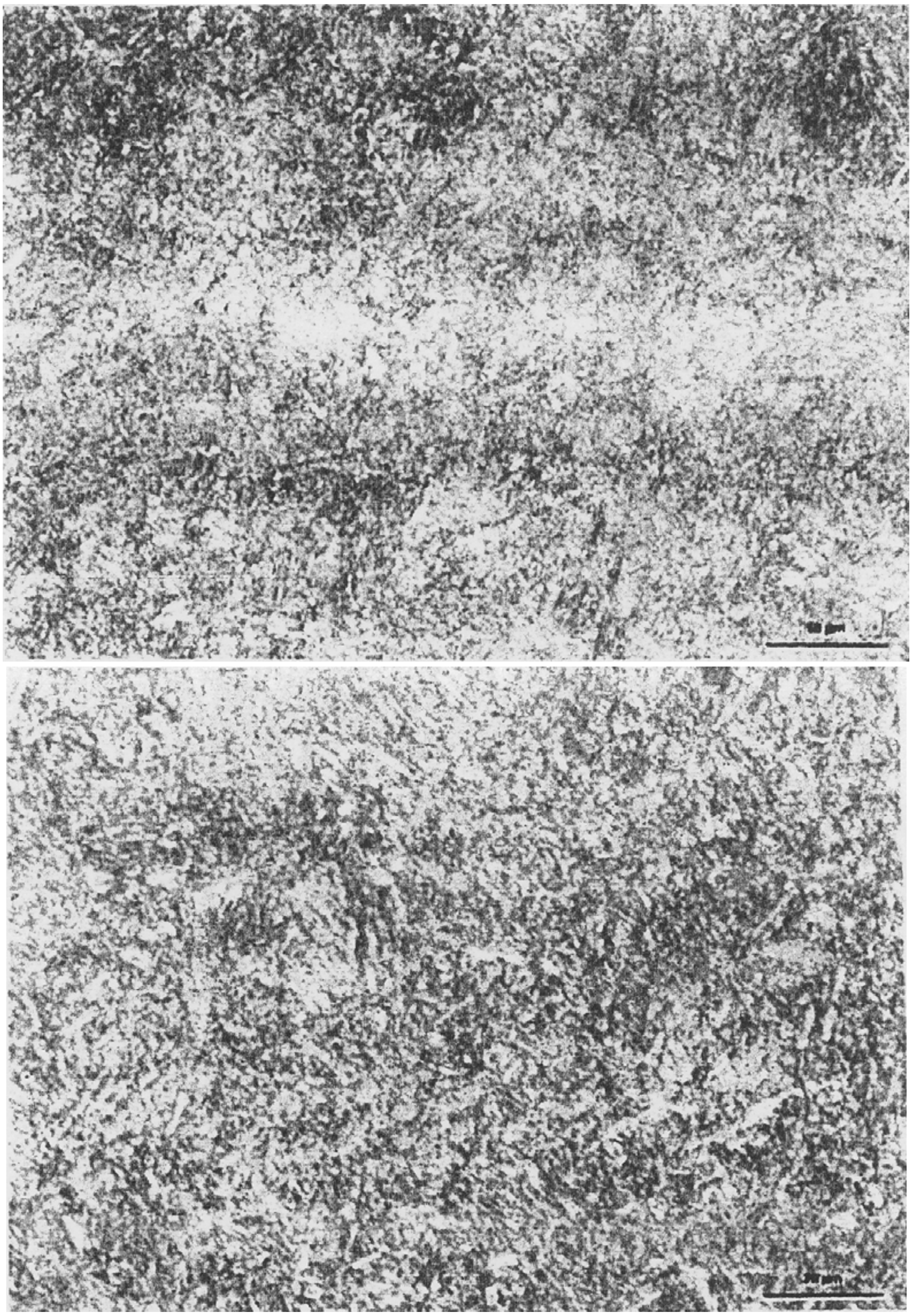


Fig. 7 Micrographic image of welded joints tested at room temperature: a- without post-weld heat treatment; b – tempering as post weld heat treatment.

At lower values of axial pressure, microstructure of the joint plane is mainly inferior bainite (figure 8), constituent that offers favourable characteristics to mechanical strength and toughness. Samples welded at higher axial pressures have in this zone a microstructure formed from grain bainite and martensite (figure 4), with lower capacity to support plastic deformations.



a

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Fig. 8 Micrographic image of welded joints central zone from the joint plane for high axial pressures.

Applying a post weld tempering heat treatment increases the toughness of the welded joint (figure 6), because quenching constituents are decomposed into a mixture of ferrite and carbides, diminishing the hardness and internal stresses. Fracture surfaces aspect became specific to a ductile fracture (figure 7b) and absorbed energy for fracture is high.

3. Conclusions

In case of friction welding QT components from the same material is recommended that an axial pressure should not exceed 200/300N/mm^2. Increasing friction pressure accentuates the negative effect of fibber deviation, temperature gradient becomes more abrupt and martensitic transformation in the joint plane can not be blocked. As a result the joint domain becomes fragile and this can not be compensate by a higher capacity of plastic deformation of the proximity material.

Appling high tempering heat treatment (580°C) after welding process has a good effect on toughness, impact energy at room temperature increasing from 15-18J to 27-30J.

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