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VISUALIZATION OF SPOT-WELDING RESISTANCE

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Abstract

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This contribution devotes to monitoring of processes running during joining of steel sheets by incadescent so called point welding using non-destructive trial method – acoustic emission (AE). The joining process is detailed described within experimental measuring from the point of view of metallurgic effects runnig during weld creation (records obtained by means of AE method). It takes into consideration quality of joined steels within welding data of steel producer. Steel welding (determined by chemical composition) during mechanical verification and firmness of welds consider results of measurement AE and fracture effect of point joints. The measurement also demonstrates conclusion about connection of metallurgic processes with material wave effects (AE measurement) and their impact on firmness of joint at steel with guaranteed welding, difficult welding and at their potential combination.

Keywords: resistance spot welding, acoustic emission, mechanical tests

INTRODUCTION

Resistance spot-welding differs from classic fusion welding by using heat created during vent of electric current of material clutched between two great conductive and internally cooled electrodes. The spot welding, seam welding and projection welding is found on that base (Hluchý and Kolouch, 2002).

During formation of spot weld there is a clutch of two (exceptionally three) sheets ususally of the same thickness (not important) same quality (from conductive material) and same vent of electric current with fusing of steel sheet surface preferentially in place of contact of clutching electrodes. After switching off current and fast heat drain from the place of fusing of sheet material the meltage solidificates and forms itself to weld in shape of lens. If the point weld has to have demanded quality the weld lens has to have optimal dimensions. The geometry depends on contact surface of electrodes tips, material conductivity (heat drain!) and heat development in gap of clutched sheets (Doubravský *et al.*, 1985). The created heat is settled by measurement of passing current within clutched material and indentation of electrodes according to Joul's principles depending on length duration of clutch. The transitional resistance is a function of height of contact surface of material and electrodes (is settled by shape of tips according to ČSN), surface profile, chemical conditions on sheets surface (dirt, oxide layers, iron scale) and measurement of specific pressure between electrodes (Ambrož, 2005). Resistant chain (resistance among individual components) lowers with measurement of clamp pressure depending on sheets thickness which affects so called effective cross-section between electrodes. The moment when the liquid phase forms it is neccessary to count on rapid growing resistance of lens of melted metal. The significant differences among individual resistances within chain resistances cause the heating inhomogeneity. The material is heated preferentially on sheets contact in weld axis due to highest current density. Then the transitional resistance lowers in this place and rises in vicinity which causes that the thickness gets bigger. In the thickness the heat is developed. The quantity of drained heat is but the fraction of created heat. A drop of melted metal is developed (weld lens) and it is closed with sheet from melting material (Hluchý *et al.*, 2002).

If the current density is not sufficient and heat drain is excessive the weld lens is not created, sheets material are not liquid enough to blend meltage in both layers. The sheets are not welded but just glued togehter. In other case the current density is excessive and the meltage is heated on the boiling point (Suchanej, 2013). Then the lens explodes due to overpressure of vapours. The liquid metal spurts out. It happens preferentially in contact of electrode tip sunk into melted sheet because the too thin overheated sheet surface bursts. Both described processes can be prevented by consistent optimalization of weld current and time. There are also more duties which have to be done (cleaning of sheet surface, maintenance of electrode tips, its sufficient cooling and check of suitable specific pressure in clutch).

The variability cases of transitional resistance appear a lot in practice. The reason is a high resistance of welded material in comparison to transitional material for example material with worsened welding, welding of inhomogeneous material and during sheets joining with different thickness (Parizek, 2013).

The quantum of drained heat is a function of many variables – dimensions of contact surface, coefficient of thermal conductivity, specific heat, specific weight, temperature and time gradient (Norek, 2013). Correct expression of thermal field described in instationary conditions is without computer modelation almost unrealistic. To set optimal conditions during weld effecting is neccessary contiunal monitoring of joint development during its formation so called in situ even followed strength verification of weld joint by the most feasible way to quality sustaining of joining process within point welding. It is one of the most realistic and economic possibility of production (Kopec, 2008).

Experimental Verification

Incandescent welding was carried out on spot welder ZSE Praha BN2023. Samples of 2 mm thickness and quality ČSN 11 373, ČSN 19 312 and combination ČSN 11 737 + 19 312

In any case one sensor with use of binding medium was placed on one of the welded sheet. The force 2 kN had an effect on samples during welding, welding current 8000 A (13 000 A) and welding times were amended within 2–5 s.

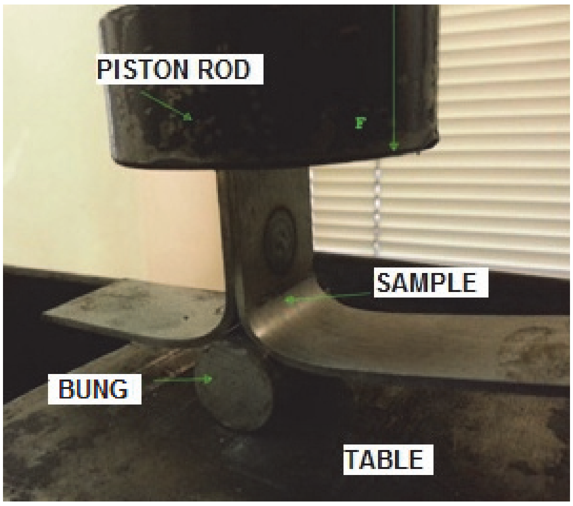
Samples Preparation

Samples made from steel ČSN 11 373 for tests were fired from steel ČSN 11 373 in dimensions 30×2×100 mm for spot welding tests. Tool steel ČSN 19 312 was delivered by firm specialized on tool steel in dimensions 30×2×500 mm. These testing flat rods were produced by machining and their surface was sharpened. The rods were cut for needed lengths on bandsaw.

Material of various welding were chosen for test due to the biggest difference of AE record and mechanical qualities of weld (NDT, 2013). The steel

1: *Spot welder ZSE Praha BN2023*

2: *Sensor placing during spot welding*



3: *Straining of samples from spot welding*

ČSN 11 373 was chosen as a material of guaranteed welding contrary to hard weld steel ČSN 19 312 according to ČSN 42 0002.

Measurement Methodology AE

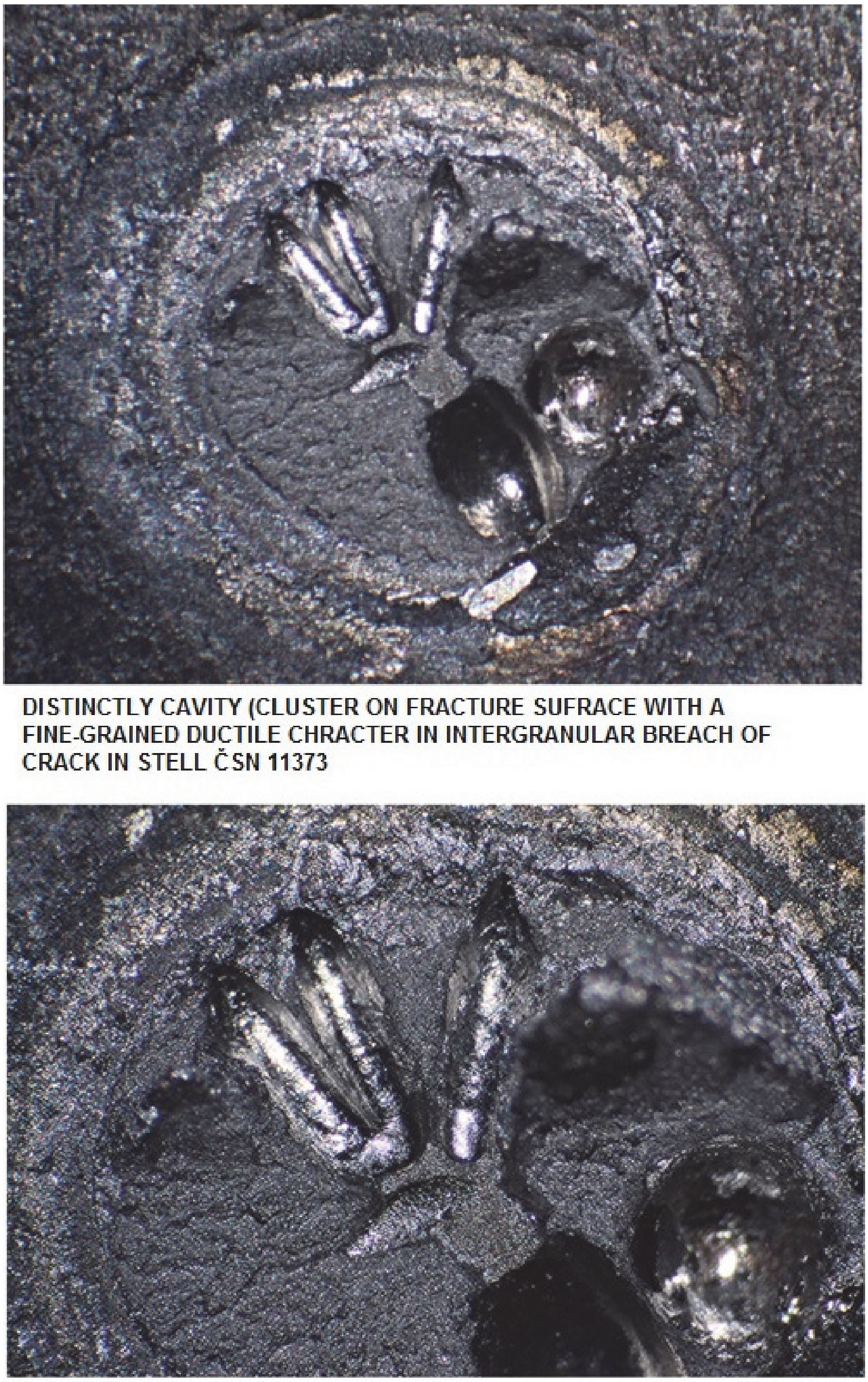
During welding was used analyser of acoustic emission Dakel IPL. This analyser was connected to PC with controlling software.

Pasted sensor Dakel MIDI and magnetic sensor MDK1 were used for measurement.

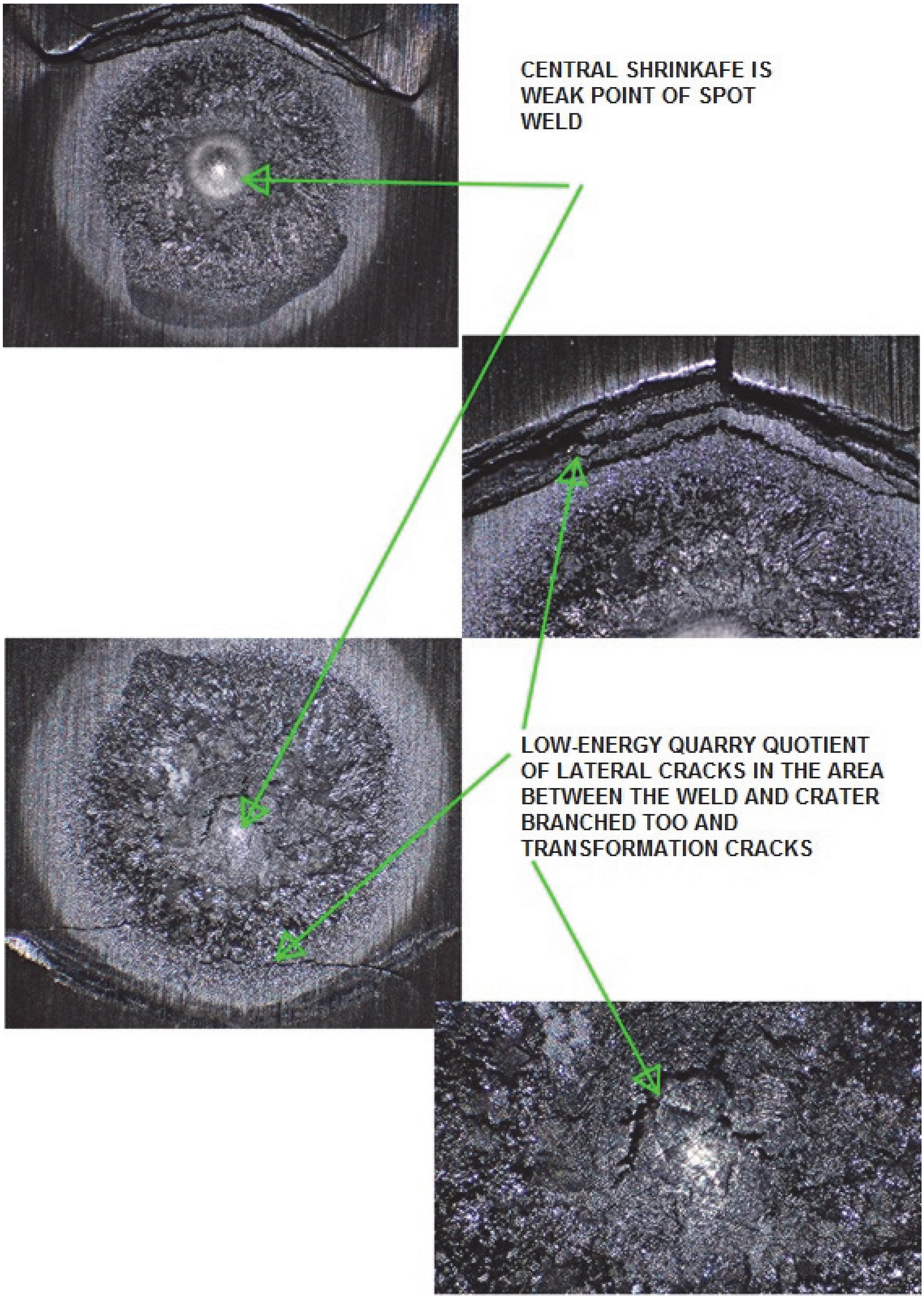
Samples from spot welding were spread out then gaped open till weld breach accros the pivot of average 18 mm.

Factual analysis of incandescended welds was carried out on metallographic binocular.

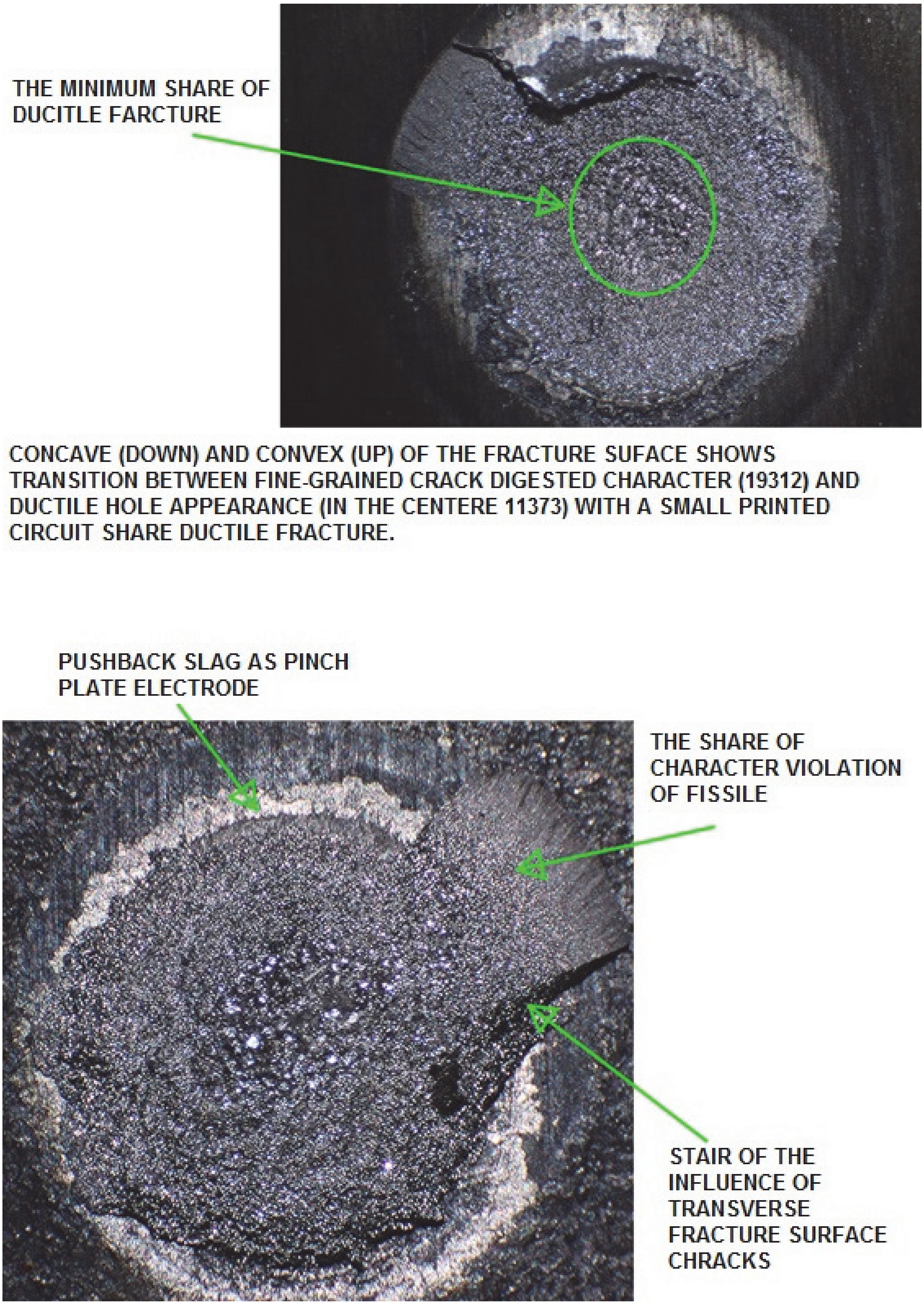
Significant cavities (clusters) on fracture surface with malleable fine-grained character breached by intercrystalline fracture at steel ČSN 11373.



4: *Photo of steel spot weld ČSN 11 373*

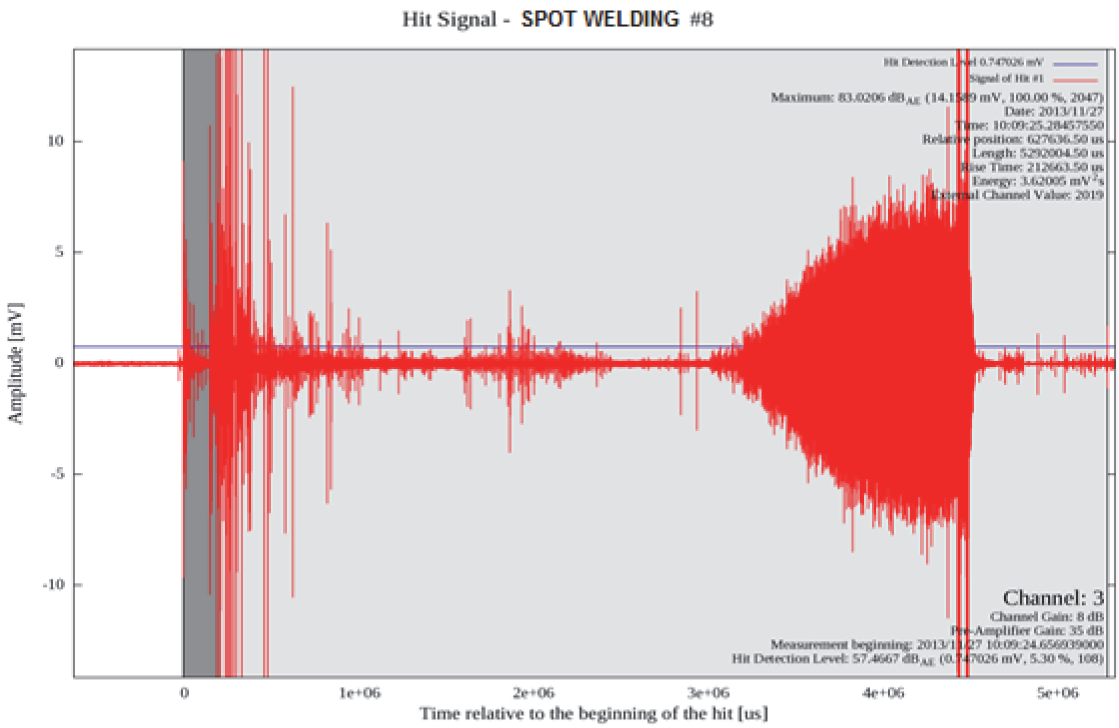


5: *Photo of steel spot weld ČSN 19 312*

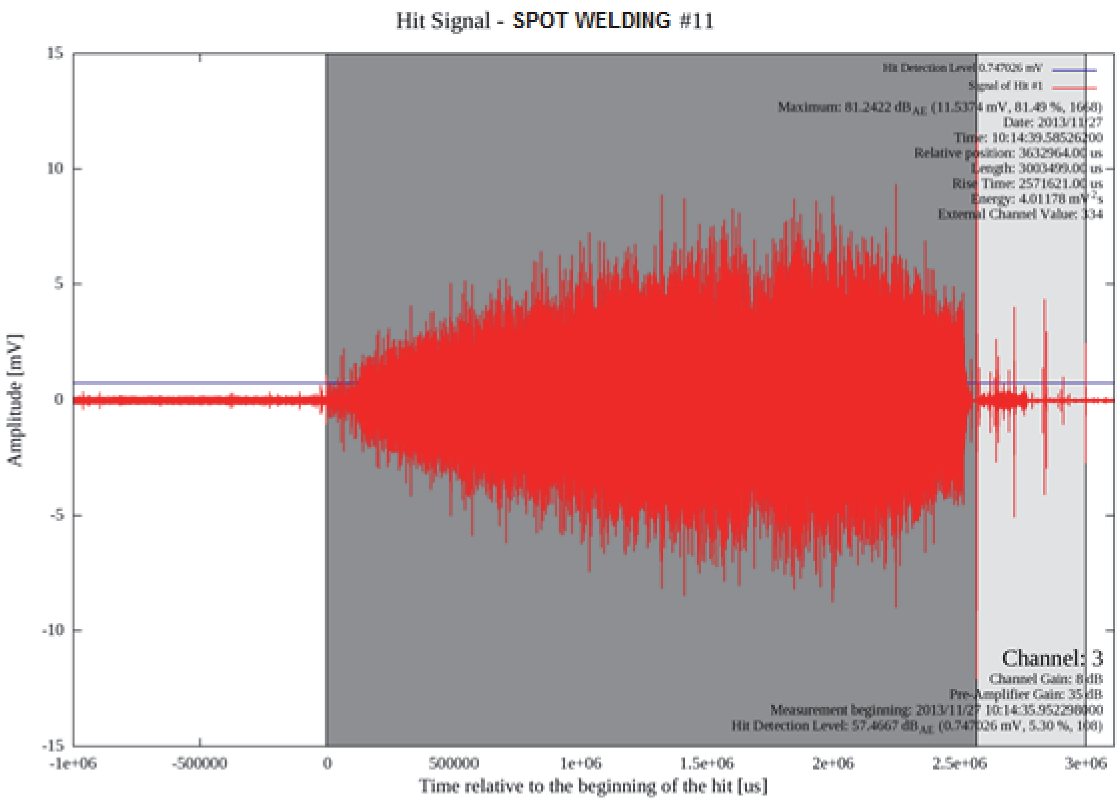


6: *Spot weld breach at combination of steel ČSN 19 312 and steel ČSN 11 373*

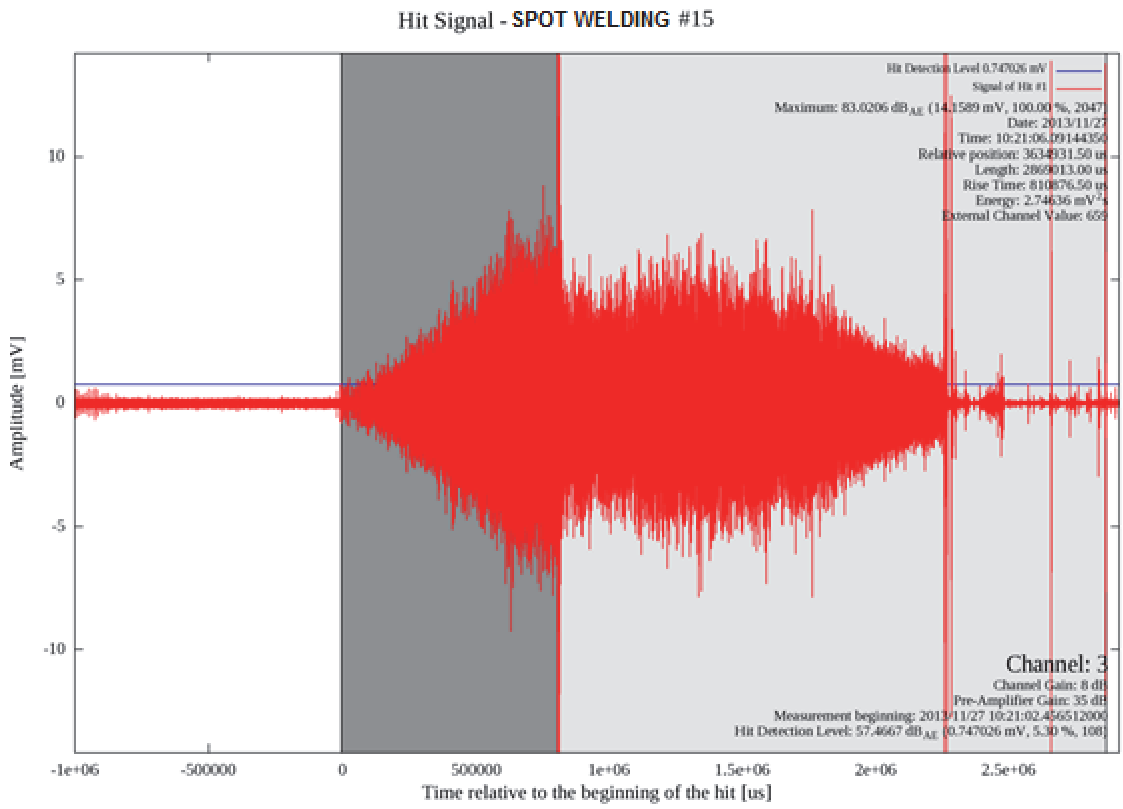
Measurement AE Results – Difference in Records



7: *Typical appearance of AE record at welding, ČSN 11373*



8: *Characteristic AE record at welding, ČSN 19312*



9: *AE at combination of steel ČSN 19312 and steel ČSN 11373*

EXPERIMENTAL RESULTS DISCUSSION

Visual check at spot welded samples did not indicate any defect. Shape and appearance of weld differed from chosen time and welding performance.

Spot welds tests were carried out by straining of gaped open samples across steel roller as described

10: *Plastic deformation "gape opening" of steel weld 11373*

11: *Brittle breach of steel weld ČSN 19 312*

12: *Breach at combined sample; centre in steel 11373 (left), brittle breach at non-welding 19312 (right)*

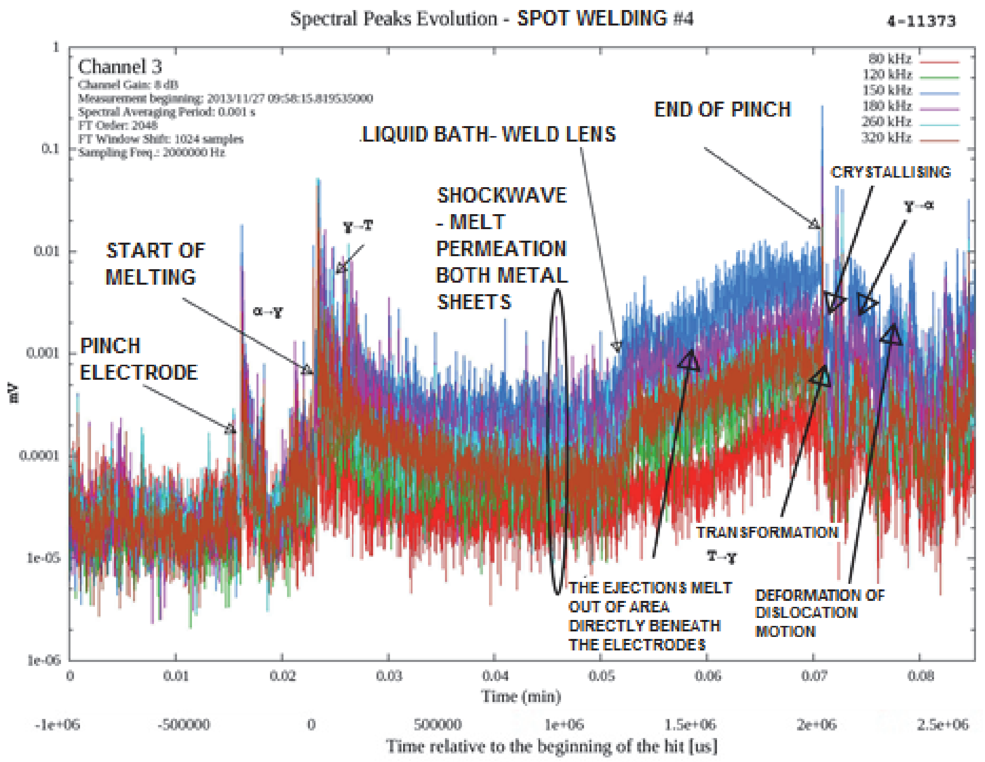
above. At steel 11 373 the straining was absorbed by plastic deformations. After sample plasticity depletion the clefts started to appear in weld and surrounding material followed by pulling out the whole weld from one of the basic material. None of the samples was completely broken – the weld breach did not occur.

At steel 19 312 the process of test was different. At minimal straining the residual energy cumulated without relaxation possibility in weld released itself and sample bursted with significant acoustic demonstration. Sample breach occured without visible plastic or elastic changes of sample dimensions. From one of the basic material the whole volume of weld was always pulled out. The fractures had gentle structure. The big cleft appeared at some samples before pulling weld out.

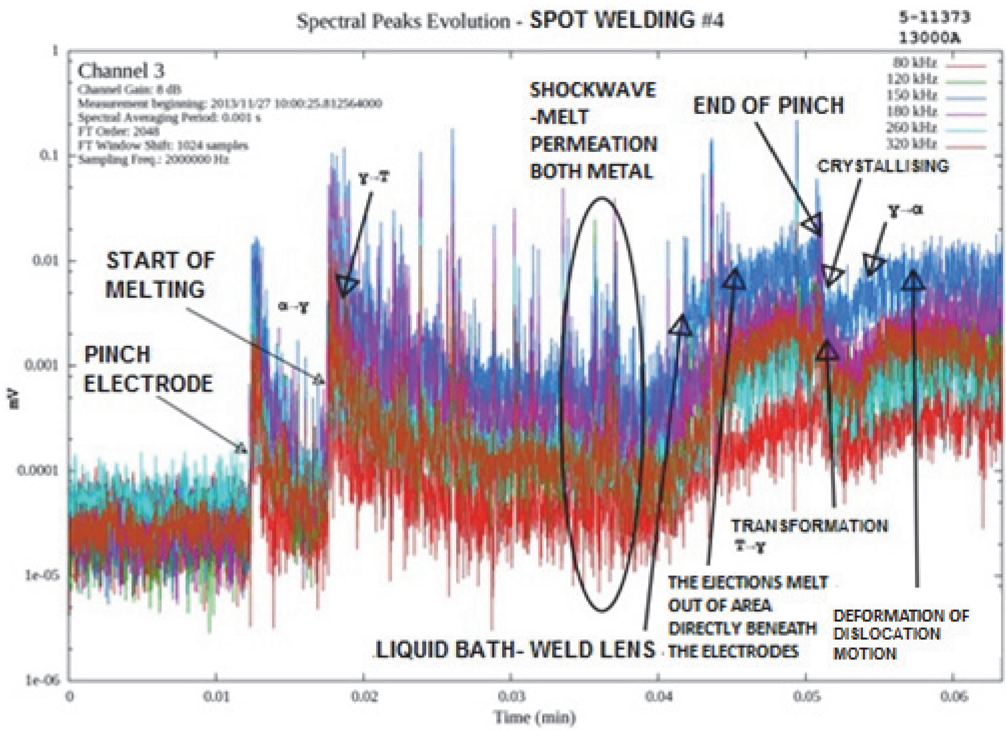
At combined samples where the basic material was composed of steel 11 373 and 19 312 was the process of test similar as at sample 19 312. At minimal straining the fregmentation of weld fleck occured by fission fracture.

RESULTS OF RECORD AE

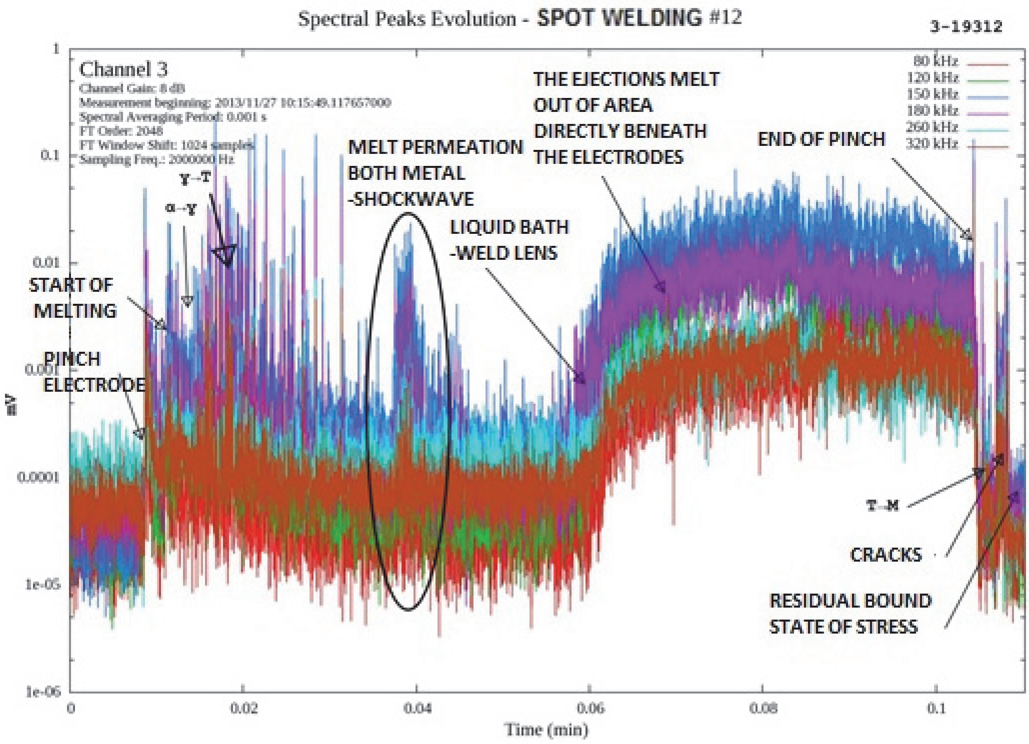
Matching hits gained in chosen time period for conditions during structural amendments is for both material (ČSN 11 373, 19 312) carried out Fig. 22.



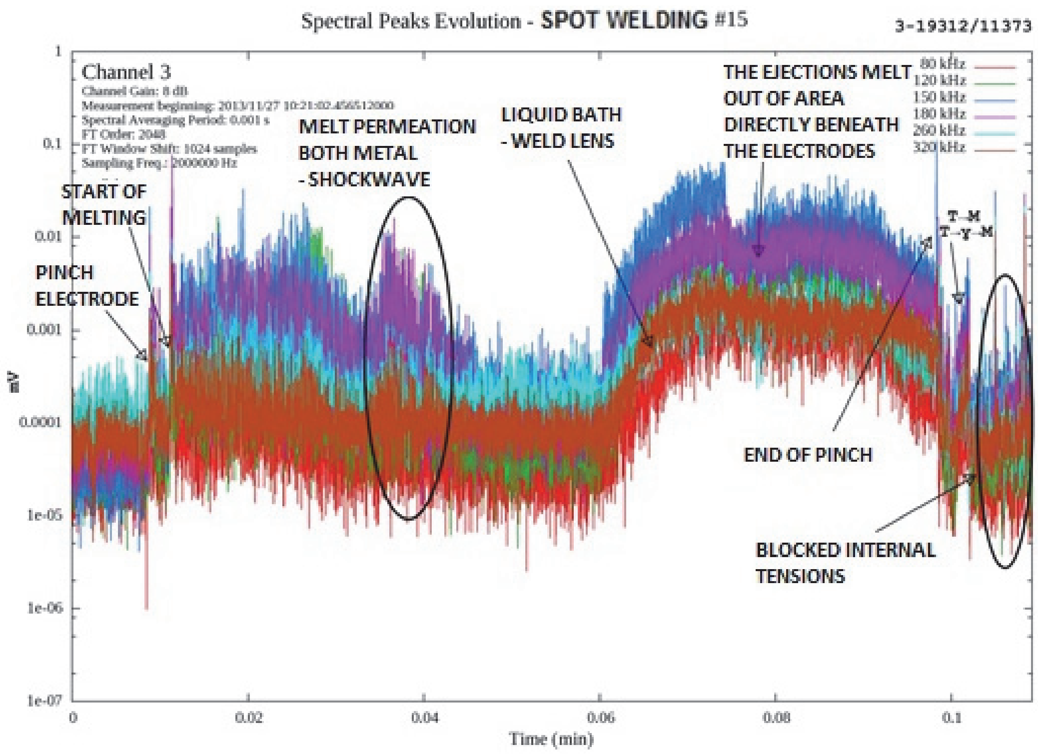
13: *Example of record AE at resistance spot welding steel ČSN 11 373*



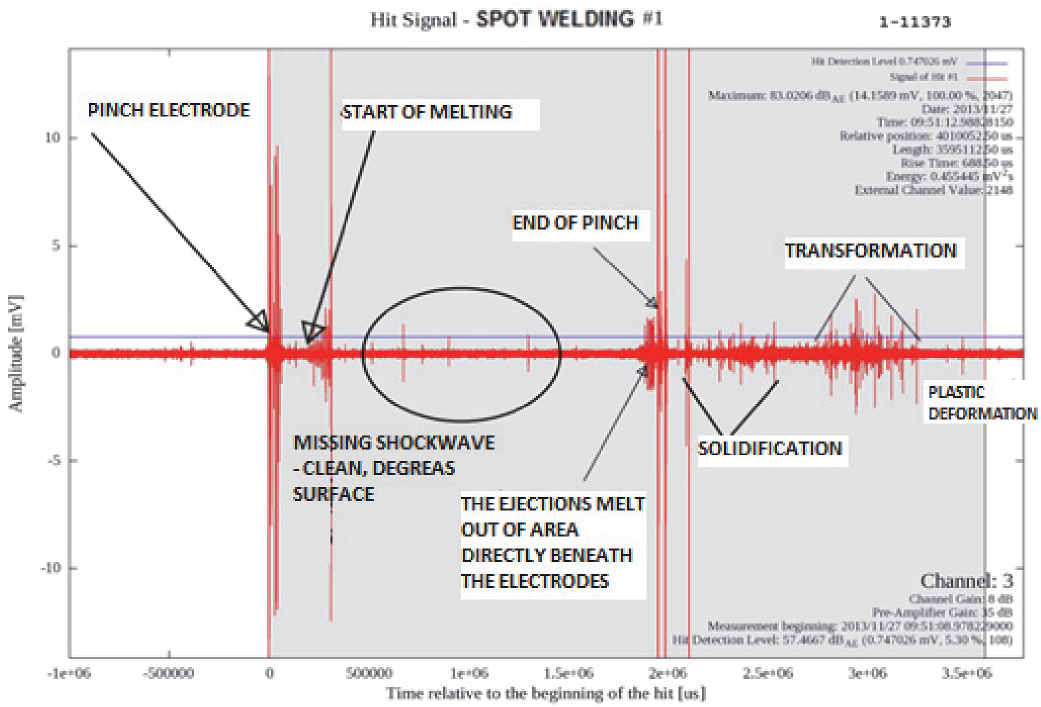
14: *Steel ČSN 11 373, current increased up to 13 000 A*



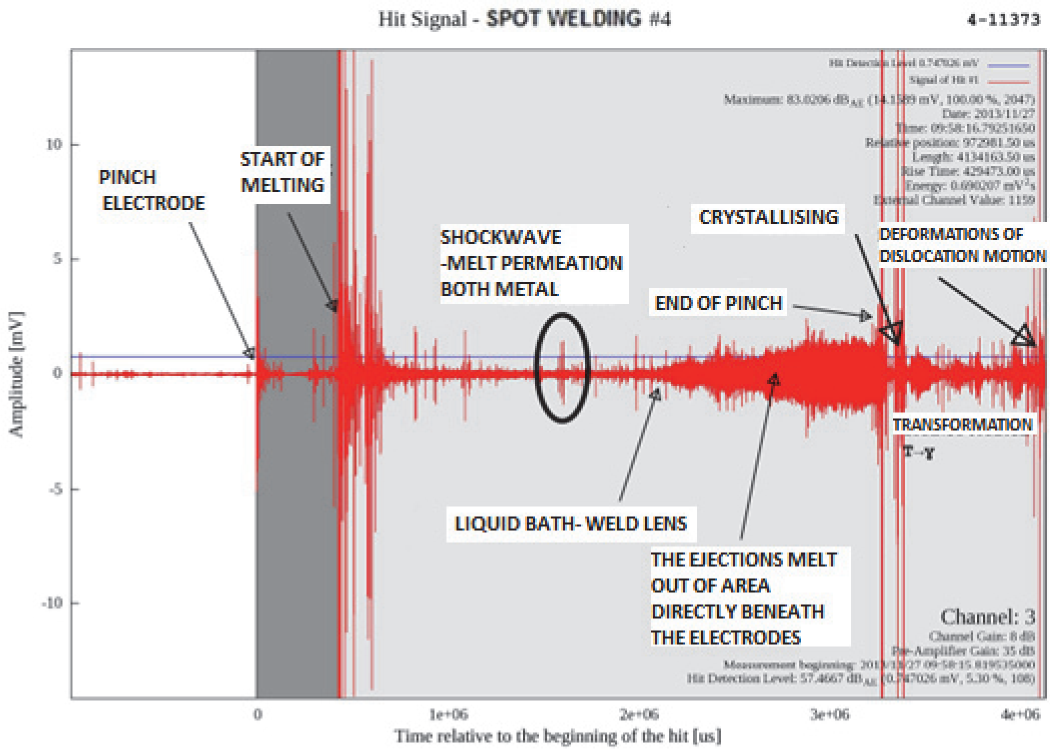
15: *Typical appearance of AE record at steel ČSN 19 312, without relaxation of tension*



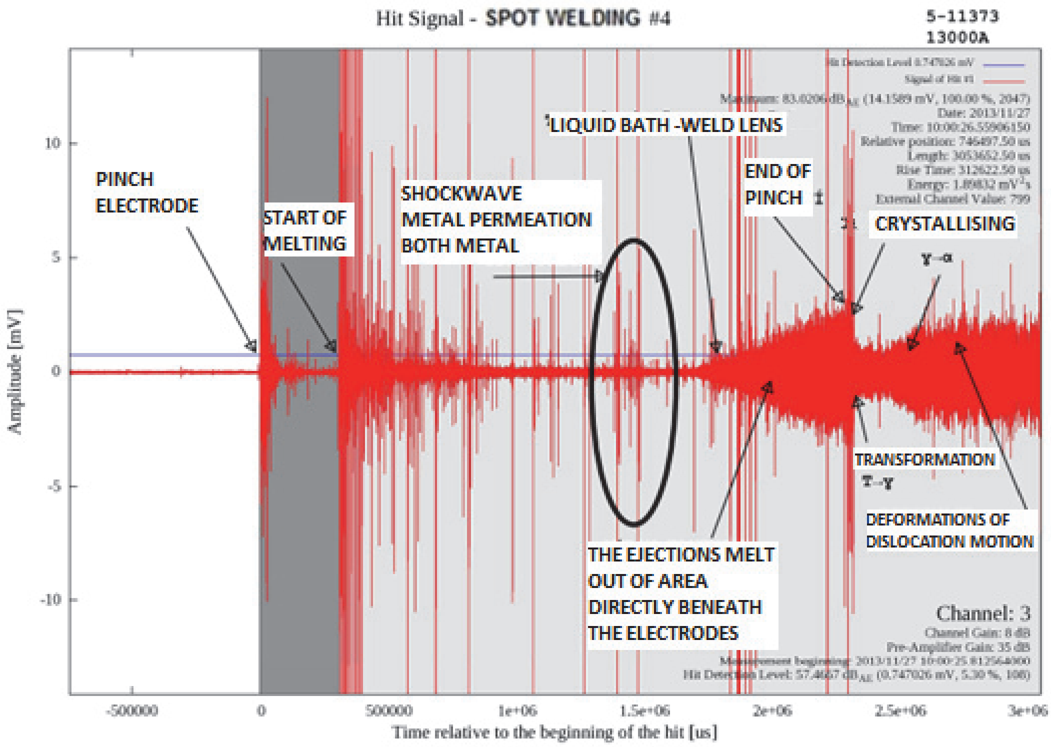
16: *Spot welding, combinaton of steel ČSN 19 312 and 11 373*



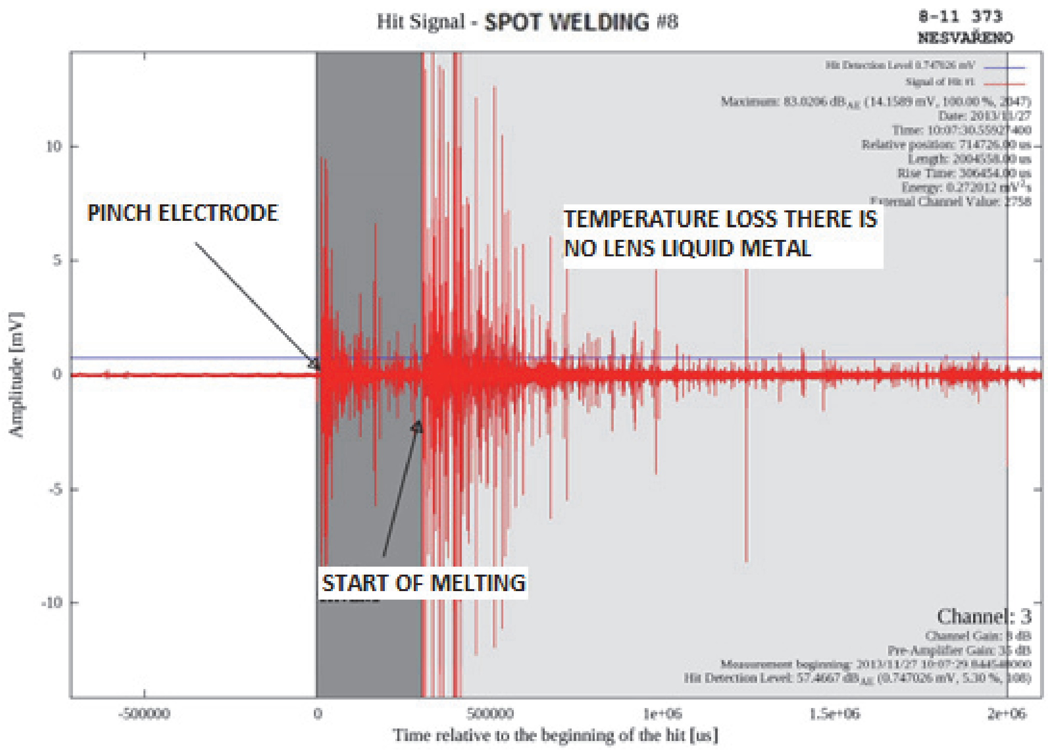
17: *AE record of low-grade welding, steel ČSN 11 373, not adjusted surface*



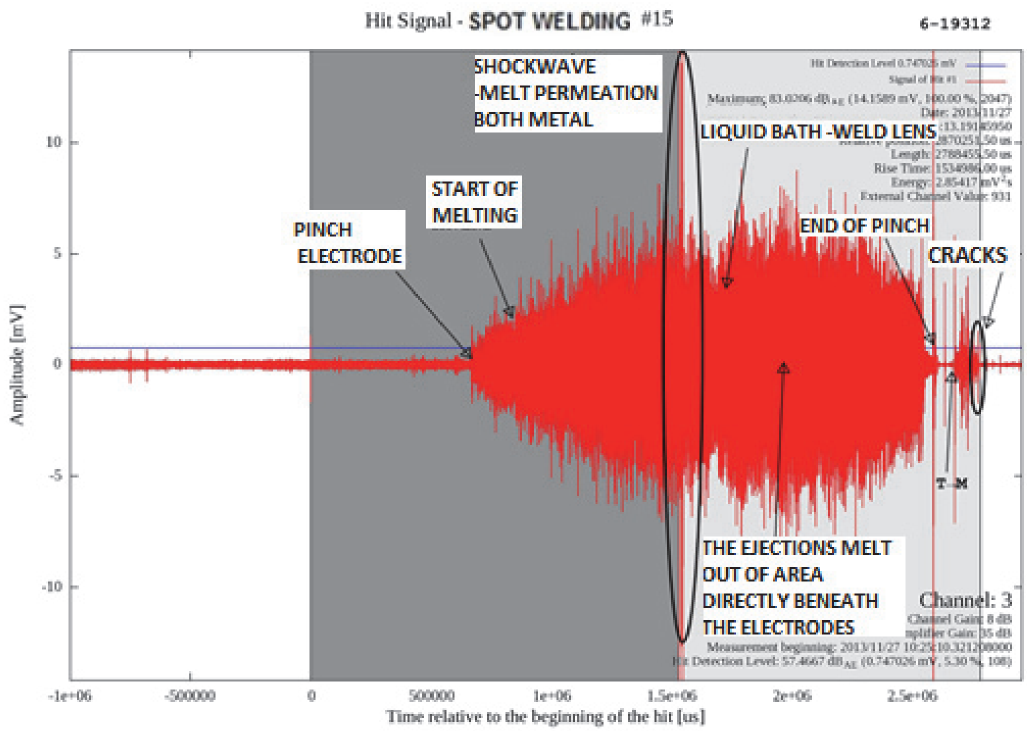
18: *Characteristic appearance of AE record at welding, steel ČSN 11 373, 8 000 A*



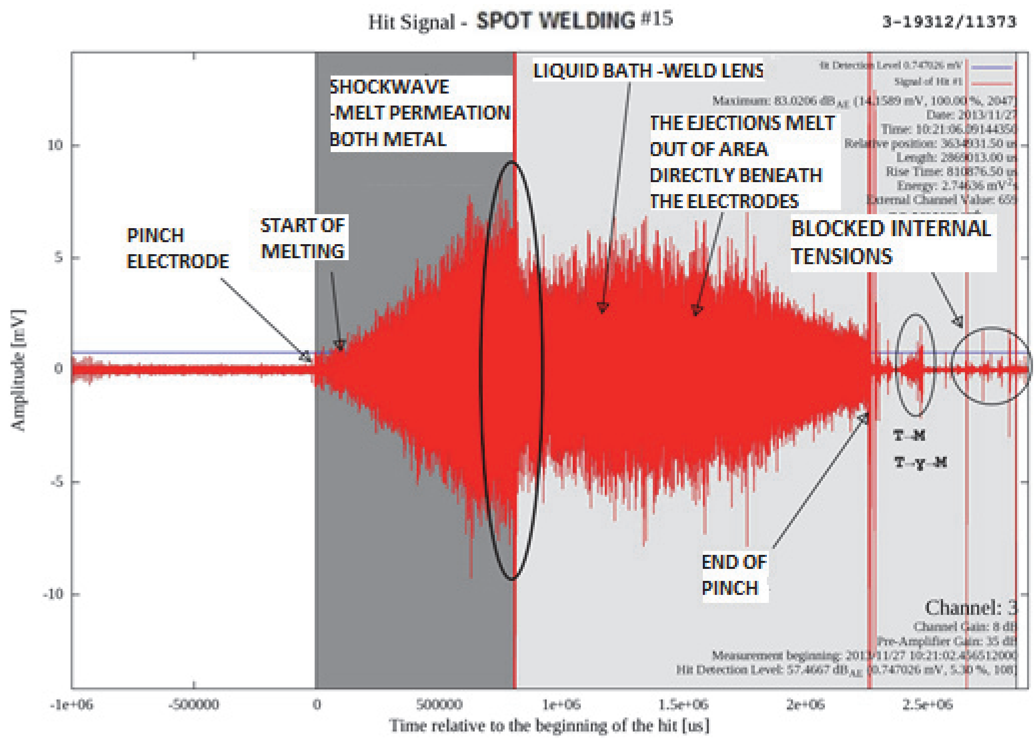
19: *Typical AE record at spot welding, steel ČSN 11 373, 13 000 A*



20: *AE record for steel ČSN 11 373, sample was not welded – adhesion*



21: *Typical AE record for steel ČSN 19 312, great emission of waves at steel overheating*



22: *Distinctive AE record for combination of steel ČSN 19 312 and 11 373, progressive melting*

FULL DISCUSSION

Discussion of results is carried out progressively within the stated figures and describtion. This discussion including gained findings at individual samples and records is completed by overall discussion which unites findings from individual visual checks, mechanical, metallographical, factographical and accoustic tests stated on figures, records. In the field of welding verification, stated by producer of semi-finished steel confirmation was gained about difference between material with guaranteed welding and hard weld material.

Regarding quality of welds carried out at guaranteed weld steel ČSN 11 373 it is obvious from gained records that after fusing there is a fluent blending of melting bath (blending of surfaces at spot welding) followed by cooling of melting bath and voltage equalizing within feritic-perlitic structure, Fig. 7. Records are added of figures from metallographical steel grinding ČSN 11 373.

At Material ČSN 19 312 there is a great surge of accoustic noise which is accompanies surge of unidirectionally oriented long dendrites. The dendrite is accompanied by shear transformation of austenite on martensite in TOO. The flat shape of record (Fig. 5) behind this transformation (for example without movement of line breach) is a proof of presence of high tenseness, rest in slump plain and creation of material brittleness which is a part on development of fission microclefts. These events have a character of absolute loss of relentless which is obvious from figure from mechanical tests of steel welds ČSN 19 312 which are more than convincing comparison to relentless at steel ČSN 11 373.

At resistance joining marked as a combination (joining material with guaranteed welding and hard welding) is obvious from both records and mechanical tests that the guaranteed steel welding ČSN 11 373 is degraded by fission joint breach due to development of brittle clefts at material ČSN 19 312 (Fig. 6). From these experience it is obvious that application AE has an asset at monitoring of creation of weld joint by spot welding. As it is obvious from the newest home contributions which survey asset of AE in the field of incandescent welding and they are subject of already approved norm in USA. The file of AE records is gradually established within prior and flowing projects which describe the quality of joint „in situ“. (in USA there is unfinished field of fusion welding by means of MAG method).

CONCLUSION

Experimental part verifies the weld quality „in situ“ comes from findings of technical literature roughly stated in theoretical part. It becomes the base for choice of experimental methodology and results assessment.

Regarding material marked by producer as a guaranteed welding and hard welding there are used three kinds of welding technology to prove it or in other case disprove it. After welding the mechanical tests along with the metallographic and factual monitoring are used to prove the firmness of quality joint (proposed by thesis writer for purposes of dissertation). It confirms the results of nondestructive process assessment of welding and appraisal of welds formation within the AE measurement. The source activity which affects the welding process is detailed caught on AE records and described as per discovered and affirmatived shapes of individual hits and overshoots at active level of each material and used technology of welding.

The findings are compared to results from both technical literature and norms (or their proposals) stated in USA (ASTM, E 751 – 01. 2001) The quality joint assessment has a completely new level which is actual weld quality assessment during its own welding process but not „post“ when the material cannot be changed and as well as the input data. By using this method the presented subject becomes very suitable for strict use in technical practice. Borrowing or actually buying of record AE apparatus including the course of instruction in some accredited workplace in CZ does not present the costs rise form point of view of mass production and larged-sized welded construction.

The AE record method could be used in future not only for weld quality assessment but also for example for quality assessment of parts pressing or assessment of running-in new machines.

Acknowledgement

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