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Computer and supercomputer technologies constructive-technological designing of responsible welded constructions Kompjuterske i superkompjuterske tehnologije konstruktivno-tehnološkog projektovanja odgovornih zavarenih konstrukcija

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Abstract

Modern idea of the design and technological design of welded structures using the latest digitalization and classical approaches. Visionary generalization of ideas for scientific and technological breakthrough in the assembly and welding process.

Welding and related technologies that make a significant contribution to the creation of gross national products of developed countries cannot remain aloof from the processes of digitalization of economies and the construction of a new postindustrial society. At the same time, intellectual procedures for the development, modeling and finalization of the design of basic welded structures operating under variable loads, are crucial. It determines the carrying capacity and resource of the technical facilities and systems being developed, as well as the structure, equipment and organization of assembly and welding operations, especially in serial manufacturing. Multivariate development of welded structures has a clearly expressed constructive and technological character. This provision was first substantiated in the works of Professor N.O. Okerblom [1]. Since the middle of the last century, this position was cautious, but later the principles of constructive and technological design of welded structures received scientific recognition, also in the International Institute of Welding. Simultaneous (parallel) design of welded structures and development of welding technologies on the basis of calculation methods was supplemented in work with scientific and methodological approaches and with the corresponding software complex for automated design of technologically necessary assembly and welding fixtures [2]. Three-dimensional solid-state computer model of a welded structure and welds

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Rezime

Savremena ideja projektovanja i tehnološkog projektovanja zavarenih konstrukcija koja koristi najnoviju digitalizaciju i klasične pristupe. Vizionarsko uopštavanje ideja za naučni i tehnološki proboj u postupku montaže i zavarivanja.

Zavarivanje i srodne tehnologije koje daju značajan doprinos stvaranju bruto nacionalnih proizvoda razvijenih zemalja ne mogu ostati podalje od procesa digitalizacije ekonomija i izgradnje novog postindustrijskog društva. Istovremeno, ključni su intelektualni postupci za razvoj, modeliranje i finalizaciju projektovanja osnovnih zavarenih konstrukcija koje rade pod različitim opterećenjima. Određuje nosivost i resurse tehničkih sredstava i sistema koji se razvijaju, kao i strukturu, opremu i organizaciju montaže i zavarivanja, posebno u serijskoj proizvodnji.

Multivarijantni razvoj zavarenih konstrukcija ima jasno izražen konstruktivan i tehnološki karakter. Ova odredba prvi put je potvrđena u radovima profesora N.O. Okerblom [1]. Od sredine prošlog veka ova pozicija je bila oprezna, ali kasnije su principi konstruktivnog i tehnološkog projektovanja zavarenih konstrukcija dobili naučno priznanje, takođe i u Međunarodnom institutu za zavarivanje. Istovremeno (paralelno) projektovanje zavarenih konstrukcija i razvoj tehnologija zavarivanja na osnovu metoda proračuna dopunjen je u radu, naučnim i metodološkim pristupima i odgovarajućim softverskim kompleksom za automatizovano projektovanje tehnološki neophodnih montažnih i zavarivačkih instalacija [2]. Trodimenzionalni računarski model stanja čvrstoće zavarene konstrukcije i zavarenih proizvoda postaje glavni izvor i nosilac projektnih i tehnoloških informacija.



becomes the main source and carrier of design and technological information.

The principles of design proposed by N.O. Okerblom, supplemented by the approach to the parallel design of technological tooling, found methodological confirmation in the concept of integrated information systems supporting all stages of the life cycle of technical objects and systems (so-called CALS-technology). It speaks of the correctness of direction of research and applied research conducted by the authors.

It is not possible to provide the process of constructive and technological development of welded structures, made of ordinary quality steels and low-alloy steels by arc welding methods, without in-depth analysis of possible internal residual stresses and deformations. Large numbers of scientific works were devoted to this direction both at the early stage of development of welding technology and at the present time. In the era of active computerization of the processes of engineering objects designing, commercial systems for finite element analysis like Ansys, Nastran, Marc, etc. are widely used for these purposes. Special software products (SYSWELD) are created by leading companies (for example, ESI Group) to simulate virtually all thermodynamic processes at welding and hardening. However, in commercial products, the features of welding technologies have not yet been adequately reflected, and specialized software products such as SYSWELD, Simufact Welding (MSC-software) are often too expensive for enterprises.

The approaches of computer forecasting of the stress-strain state (SSS) of welded constructions on the basis of the analysis of well-known works and simplified theories of occurrence of residual stresses and deformations are proposed in [4, 5]. At the initial stages of research, development of Vinokurov's approaches [3] seemed expedient on fictitious shrinkage longitudinal and transverse forces. However, further research and computational supercomputer experiments by commercial LS-DYNA system of nonlinear finite element analysis have refuted to some extent the existence of a fictitious shrink force and confirmed the expressed by N.O. Okerbolom in the 40s of the last century the idea of a mobile three-dimensional area of the weld, which is in a complex three-dimensional stress state.

The study of other authors, as well as instrumental measurements on real welded samples and welded structures, showed that mentioned above stresses are very close to the yield point of the base metal [7]. The ideas of the authors of [4,5], found

Principi projektovanja koje je predložio N.O. Okerblom, dopunjen pristupom paralelnog projektovanja tehnološkog alata, pronašao je metodološku potvrdu u konceptu integrisanih informacionih sistema koji podržavaju sve faze životnog ciklusa tehničkih objekata i sistema (tzv. CALS-tehnologija). Govori o ispravnosti smera i primenjenih istraživanja od strane autora.

Nije moguće obezbediti proces konstruktivnog i tehnološkog razvoja zavarenih konstrukcija, izrađenih od čelika običnog kvaliteta i niskolegiranih čelika postupcima elektrolučnog zavarivanja, bez dubinske analize mogućih unutrašnjih zaostalih naprezanja i deformacija. Ovom pravcu posvećen je veliki broj naučnih radova, kako u ranoj fazi razvoja tehnologije zavarivanja, tako i u današnje vreme. U doba aktivne informatizacije procesa projektovanja inženjerskih objekata, u te svrhe se široko koriste komercijalni sistemi za analizu konačnih elemenata poput Ansis, Nastran, Marc, itd. Posebne softverske proizvode (SISVELD) kreiraju vodeće kompanije (na primer, ESI Group) kako bi simulirale gotovo sve termodinamičke procese zavarivanja i otvrdnjavanja. Međutim, u komercijalnim proizvodima, karakteristike tehnologija zavarivanja još uvek nisu adekvatno odražene, a specijalizovani softverski proizvodi poput SISVELD, Simufact Velding (MSC-sofver) su često previše skupi za preduzeća.

Pristupi računarskog predviđanja stanja naprezanja (SSS) zavarenih konstrukcija na osnovu analize dobro poznatih radova i pojednostavljenih teorija pojave zaostalih napona i deformacija predloženi su u [4, 5]. U početnim fazama istraživanja, Vinokurov pristup [3] činio se svrsishodnim na fiktivnom smanjivanju uzdužnih i poprečnih sila. Međutim, dalja istraživanja i računarski eksperimenti superkompjuteru komercijalnim LS-DYNA sistemom nelinearnih analiza konačnih elemenata u određenoj su meri opovrgli postojanje fiktivne sile skupljanja i potvrdili iskaz N.O. Okerbolom koji je 40-ih godina prošlog veka zamenu mobilnu trodimenzionalnu oblast zavarenog spoja, koja je u složenom trodimenzionalnom naponskom stanju.

Studija drugih autora, kao i instrumentalna merenja stvarnih zavarenih uzoraka i zavarenih konstrukcija, pokazali su da su pomenuti naponi vrlo blizu naponu tečenja osnovnog materijala [7]. Ideje autora [4,5] našle su teorijsku i praktičnu potvrdu u radu japanskih kolega [6]. Savremena sredstva za geometrijsko modeliranje i izradu stanja čvrstoće pomoću 3D modela zavarenih konstrukcija kao što su SolidWorks, Inventor, NKS, ProE, itd., Kao i ugrađeni (ili se zasebno koriste) univerzalni



theoretical and practical confirmation in the work of Japanese colleagues [6]. Modern means of geometric modeling and construction of solid-state 3D models of welded structures and welds such as SolidWorks, Inventor, NX, ProE, etc., as well as built-in (or used separately) universal program modules of classical finite element analysis, linked to original approaches authors for computer forecasting of SSS, allow to present the scheme for integrating the processes of design of welded structures (Fig. 1). The bi-directional arrows in Fig. 1 emphasize the parallel (simultaneous) nature of all design and engineering procedures. Operational reflection of the interaction of the internal SSS of the welded structure with external loads allows more reasonably to see the influence of technological heredity on the behavior of the structures in real operation.

programski moduli klasične analize konačnih elemenata, povezani sa originalnim pristupima autora za računarsko predviđanje SSS-a, omogućavaju da predstave šemu za integrisanje procesa projektovanja zavarenih konstrukcija (slika 1). Dvosmerne strelice na slici 1 naglašavaju paralelnu (istovremeno) prirodu svih procedura projektovanja i inženjeringa. Operativni odraz interakcije unutrašnjih SSS zavarene konstrukcije sa spoljnim opterećenjima omogućava razumnije sagledavanje uticaja tehnološkog okruženja na ponašanje konstrukcija u stvarnom radu.

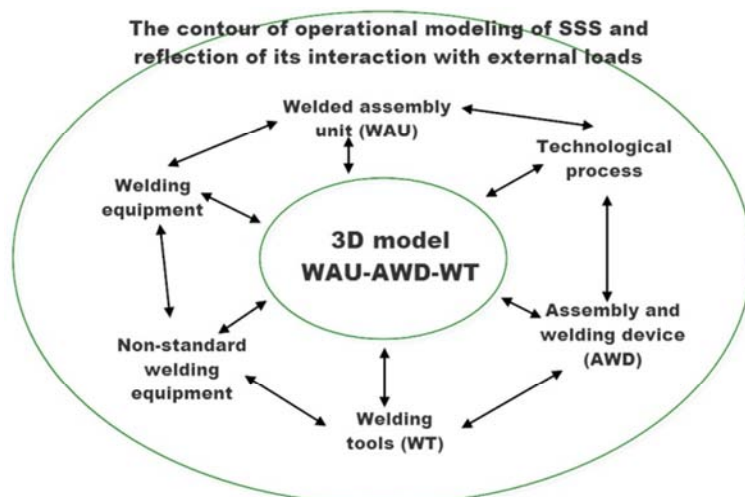


Figure 1. Scheme of integrating the processes of design and technological design of welded structures of general purpose

Slika 1. Shema integrisanja procesa projektovanja i tehnološkog projektovanja zavarenih konstrukcija opšte namene

Proposed scheme provides the ability to track the change in the resulting SSS welded structure, taking into account the design of the rigging, installation and clamping schemes, assessing the availability (reachability) of welded seams by welding tools, given the orientation of the tools, taking into account the results of a computer or automated work in the system of welding engineer fixture design instrument (INSVAR).

On modern welded structures operating under difficult operating conditions under dynamic loads, the total length of auxiliary and main welds can reach tens and hundreds of meters.

So as an example the length of welds on the supporting frame of a 220 tons mining truck exceeds several kilometers. To analyze the SSS of such responsible welded structures, especially under conditions of dynamic loading, traditional personal computer equipment and even graphic

Predložena šema pruža mogućnost praćenja promene rezultirajuće SSS zavarene konstrukcije, uzimajući u obzir projektovanje ugradnje, instalacije i stezanja, procenjujući dostupnost (dostižnost) zavarenih šavova zavarivačkim alatima, vezano za orijentaciju alata, uzimajući u obzir rezultate računarskog ili automatizovanog rada u sistemu instrumenata za projektovanje inženjera zavarivanja (INSVAR).

Na modernim zavarenim konstrukcijama koje rade pod otežanim uslovima rada pod dinamičkim opterećenjima, ukupna dužina pomoćnih i glavnih zavarenih spojeva može dostići desetine i stotine metara.

Kao primer, dužina zavora na nosećem ramu rudarskog kamiona od 220 tona prelazi nekoliko kilometara. Za analizu SSS tako odgovornih zavarenih konstrukcija, posebno u uslovima dinamičkog opterećenja, tradicionalna oprema za



stations is clearly not sufficient. To simulate similar processes and phenomena the authors have successfully used the capabilities of the national scientific and educational Grid-network of the Republic of Belarus with high-performance supercomputers of SKIF family (www.uiip.bas-net.by). The designers of engineering constructions can get remote access to these resources with the developed licensed software through the Internet from computers located at their workplaces.

Figure 2 shows a scheme for comprehensive compression of the zone of irreversible plastic deformations, whose outer boundary is generally limited to an isotherm at 600 ° C. Attention is drawn to the fact that the cross section of the seam (as the theory of welding stresses and deformations says) is stretched in the cross section.

lični računar, pa čak i grafičke stanice, očito nije dovoljna. Da bi simulirali slične procese i pojave, autori su uspešno koristili mogućnosti nacionalne naučne i obrazovne Grid mreže Republike Belorusije sa visoko performansnim superračunarima porodice SKIF (vww.uiip.bas-net.bi). Projektanti inženjerskih konstrukcija mogu dobiti udaljeni pristup tim resursima pomoću razvijenog licenciranog softvera putem Interneta sa računara koji se nalaze na njihovim radnim mestima.

Na slici 2 prikazana je šema za sveobuhvatno sabijanje zone nepovratnih plastičnih deformacija, čija je spoljna granica uglavnom ograničena na izotermu na 600°C. Pažnja se skreće na činjenicu da je poprečni presek šava (kako teorija zavarivanja naglašava a deformacije kažu) je rastegnut po preseku.

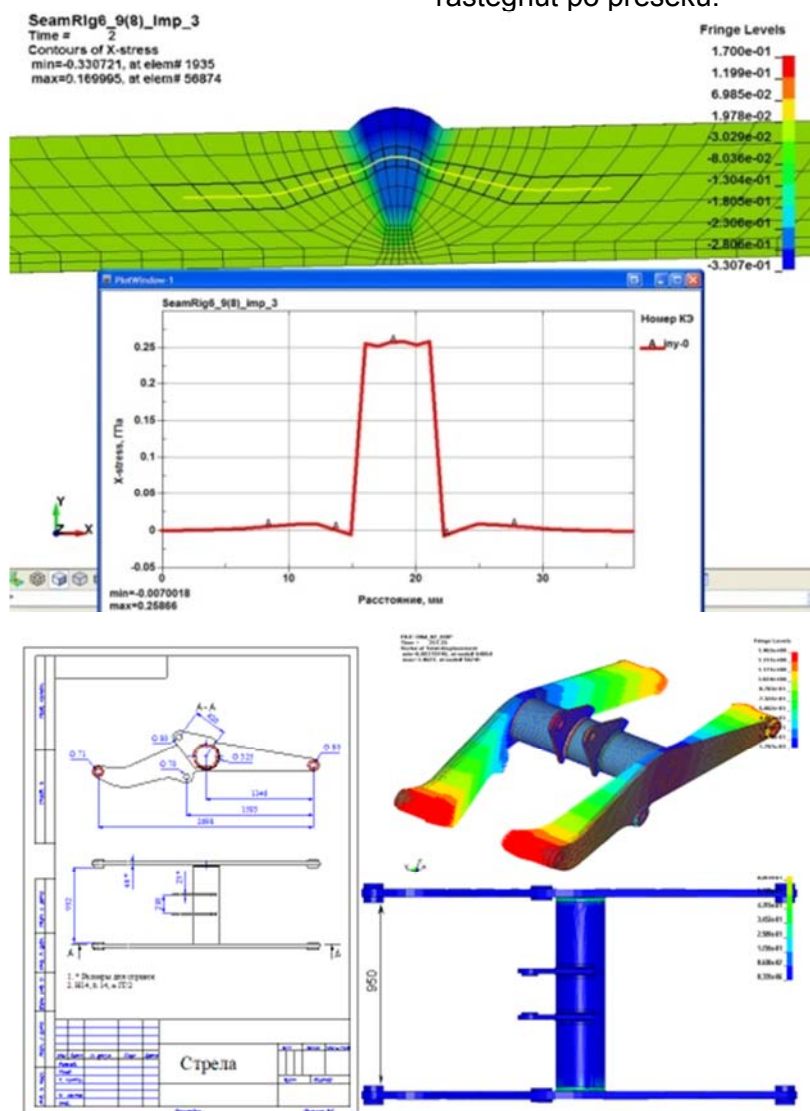


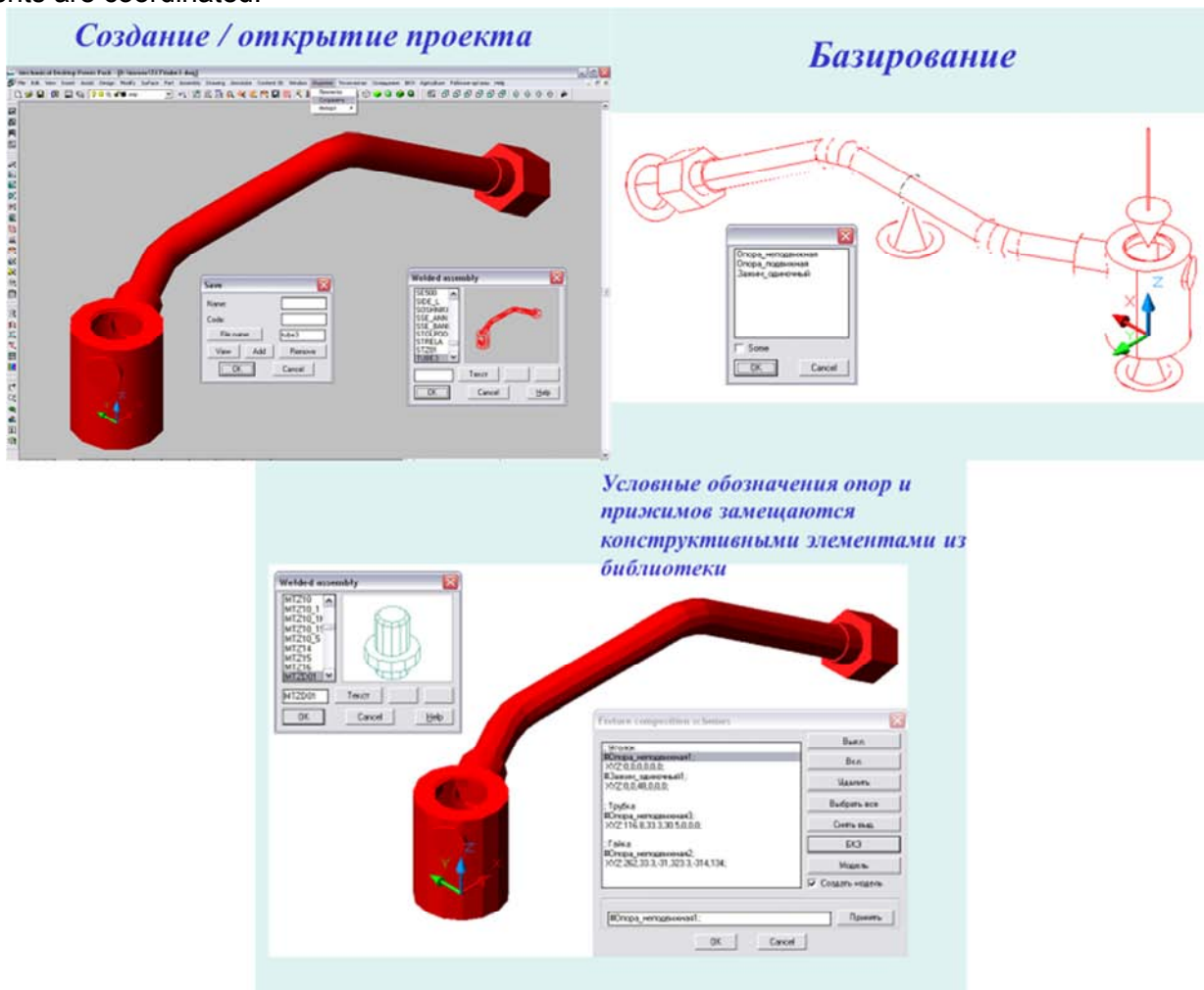
Figure 2. Comprehensively compressed weld zone and an example of the prediction of total residual welding deformations

Slika 2. Sveobuhvatno sabijena zona zavarivanja i primer predviđanja ukupnih zaostalih deformacija usled zavarivanja



Several assembly and welding fixtures designed in INSVAR are shown in Figure 3. The designer engineer of the tooling first determines the most rational position of the welding structure in 3D space during assembly and welding, then he fixes his technological design in special environment in the form of a schematic diagram of the device, then he indicates the preferred types and design parameters of the installation elements, fixation and clamps. Further, the software complex, according to its original algorithms, places the functional elements in relation to three-dimensional model of the welded structure and then unites them with the selected type of housing and later generates automatically the assembly drawing of the device structure on several projections on the projection connection. The specification of the assembly drawing is automatically generated, as well as the assembly drawings of the original parts and the selected housing type. On the housing drawing all the holes for installation on the body of functional elements are coordinated.

Na slici 3. prikazano je nekoliko montažnih i zavarivačkih elemenata dizajniranih u INSVAR-u. Inženjerski projektant alata prvo utvrđuje najracionalniji položaj zavarivačke konstrukcije u 3D prostoru tokom montaže i zavarivanja, a zatim svoj tehnološki projekat fiksira u posebnom okruženju u obliku šematskog dijagrama uređaja, onda on ukazuje na poželjne tipove i konstrukcijske parametre instalacionih elemenata, fiksatora i stezaljki. Nadalje, softverski kompleks, prema svojim originalnim algoritmima, postavlja funkcionalne elemente u odnosu na trodimenzionalni model zavarene konstrukcije, a zatim ih ujedinjuje s odabranim tipom kućišta, a kasnije automatski generiše sklopni crtež strukture uređaja na nekoliko projekcije na projekcijskoj vezi. Specifikacija crteža za montažu automatski se generiše, kao i sklopni crteži originalnih delova i odabranog tipa kućišta. Na crtežu na kućištu su koordinate svih otvora za ugradnju na telo funkcionalnih elemenata.



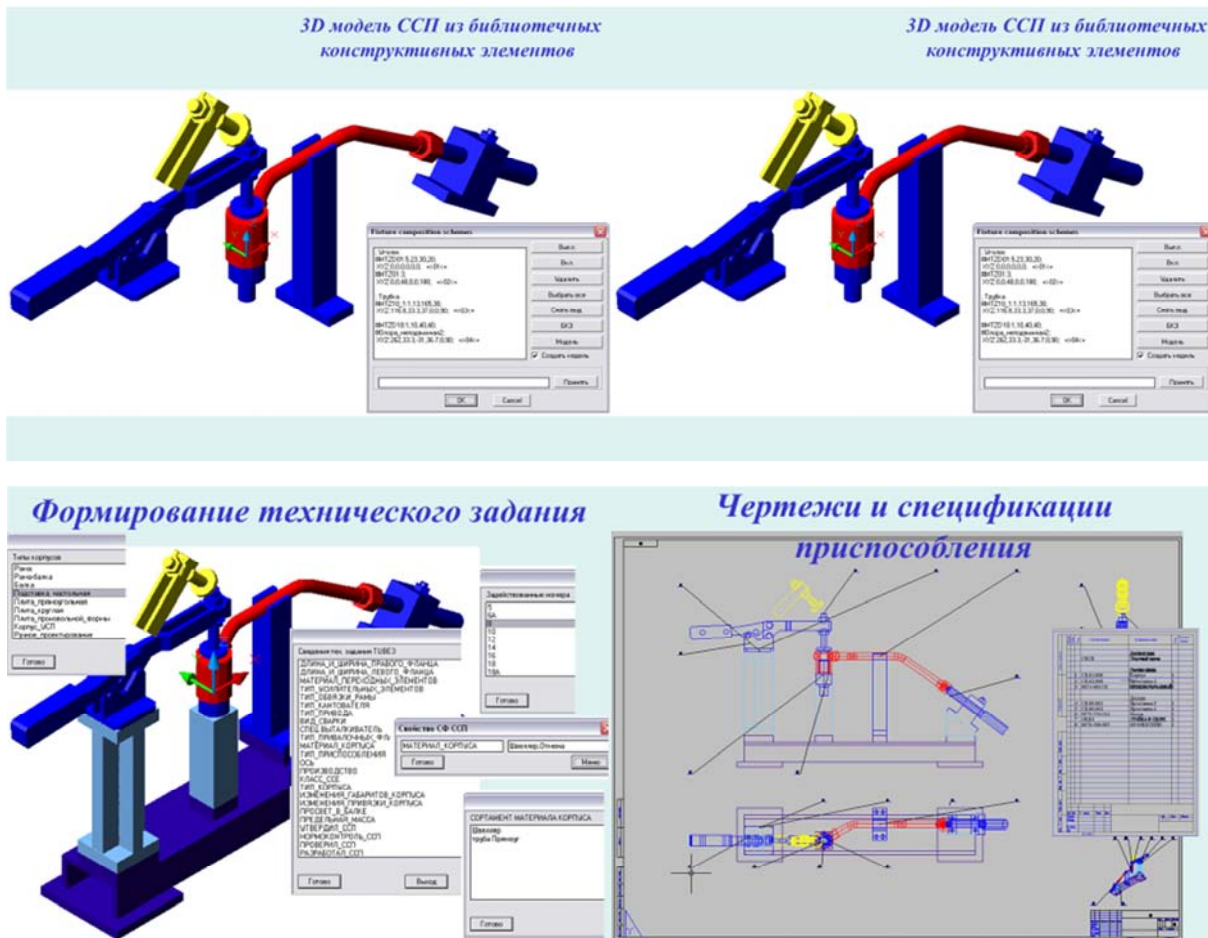


Figure 3. An example of the design of an assembly and welding device formed by the INSVAR software package
 Slika 3. Primer dizajna uređaja za montažu i zavarivanje formiranog softverskim paketom INSVARe

On the Figure 4 as an example pre-stressed after welding structure of the skeleton of an armored vehicle is subjected to a virtual impact of a shock blast wave. The displacements and stresses after explosion on the same structural elements are different, and this difference can be even more pronounced in the case of repeated short-term loads and prolonged operation.

Na slici 4, je dat primer prednapregnute nakon zavarivanja, konstrukcije skeleta oklopnog vozila koja je izložena je virtuelnom uticaju udarnog talasa. Pomeranja i napreznja nakon eksplozije na istim konstrukcijskim elementima su različita, a ta razlika može biti još izraženija u slučaju ponovljenih kratkotrajnih opterećenja i produženog rada.

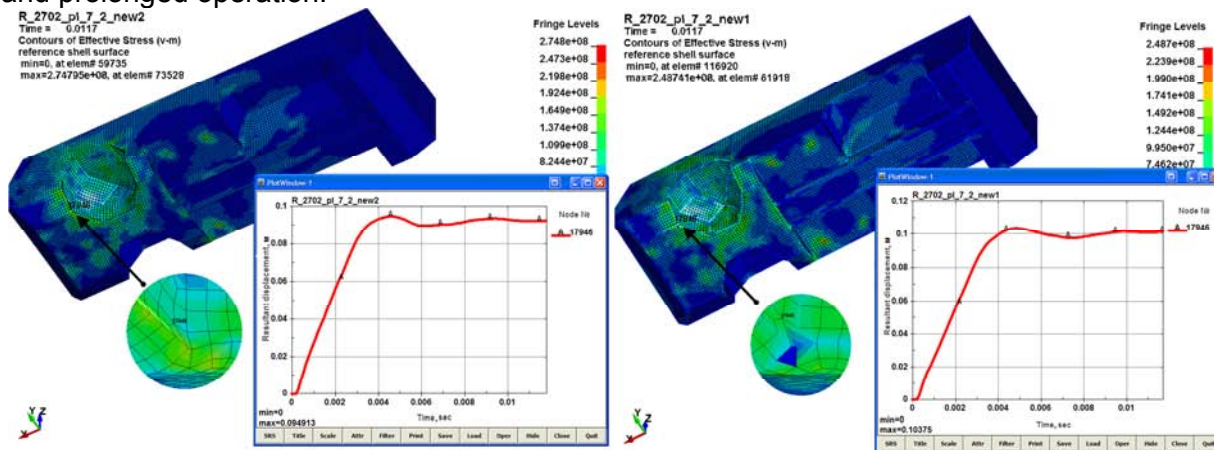


Figure 4 Difference in movements of isotropic and welded structures at the same dynamic impact
 Slika 4 Razlika u kretanju izotropnih i zavarenih konstrukcija pod istim dinamičkim uticajem



Figure 5 again confirms the well-known welding position that welded joints made without obvious defects under dynamic loads are destroyed in heat-affected zone or on the main material.

Slika 5 ponovo potvrđuje dobro poznati položaj zavarivanja tako da se izvedeni zavareni spojevi bez očiglednih oštećenja pod dinamičkim opterećenjima uništavaju u zoni uticaja toplote ili osnovnog materijalu.

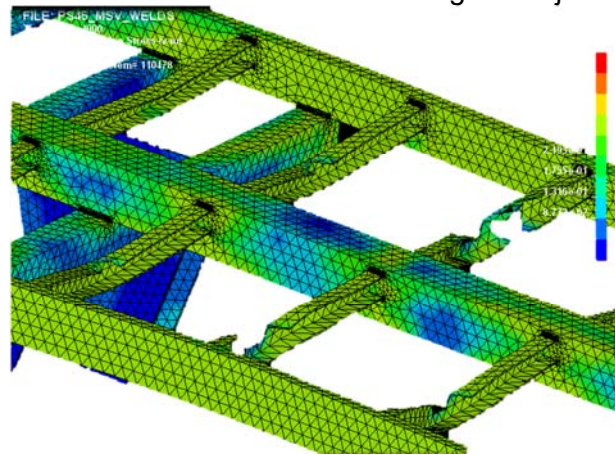


Figure 5 Destruction of the trailer model in the main metal
Slika 5 Uništavanje modela prikolice u osnovnom materijalu

Computer and supercomputer technologies for the design and technological design of welded structures are used by a number of Belarusian enterprises with a developed assembly and welding process. With their help, students are trained at the Department of Powder Metallurgy, Welding and Technology of Materials of the Belarusian National Technical University by carrying out course and diploma theses. The engineering and technical personnel of new formation, mastering the methods of constructive and technological design of welded structures using supercomputer, grid and cloud technologies, are able to provide a certain scientific and technological breakthrough in the assembly and welding process (Figure 6). The authors try to take the attention of scientists, designers, engineers and university teachers to this kind of mutually beneficial work.

Računarske i superračunarske tehnologije za projektovanje i tehnološko projektovanje zavarenih konstrukcija koriste mnoga beloruska preduzeća sa razvijenim postupkom montaže i zavarivanja. Uz njihovu pomoć, studenti se obučavaju na Katedri za metalurgiju praha, zavarivanje i tehnologiju materijala Beloruskog nacionalnog tehničkog univerziteta izvođenjem kurseva i izradom diplomskih radova. Inženjerski i tehnički kadar nove formacije, koji savladavaju metode konstruktivnog i tehnološkog projektovanja zavarenih konstrukcija korišćenjem superračunarske, mrežne i tehnologije oblaka, u stanju su da pruže izvestan naučno-tehnološki iskorak u postupku montaže i zavarivanja (slika 6). Autori pokušavaju da skrenu pažnju naučnika, projektanata, inženjera i univerzitetskih nastavnika na ovakav obostrano koristan rad.

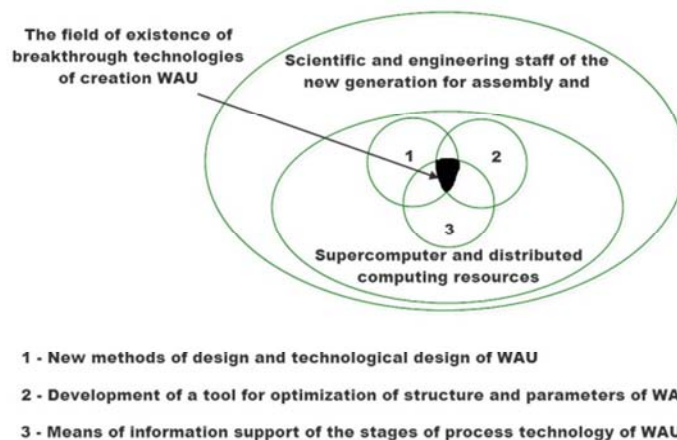


Figure 6 Scheme of the appearance of the area of scientific and technological breakthrough in the development of promising welded structures

Slika 6. Šema pojave područja naučnog i tehnološkog proboja u razvoju perspektivnih zavarenih konstrukcija



Conclusion

1. The authors have promoted the principles of constructive and technological design of welded structures, recognized by the world welding community, formulated by N.O. Okerblom, on infrastructural and computational level.

2. Approaches N.O. Okerblom is supplemented by a powerful functional and software tools for automated design of the assembly and welding fixtures, stands, conductors, etc.

3. Original methods and computer software, based on simplified theories of welding stresses and deformations, allow to predict the nature and magnitude of residual welding deformations with sufficient for engineering practice accuracy, also including taking into account the effect of fastening in technological equipment.

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Zaključak

1. Autori su promovisali principe konstruktivnog i tehnološkog projektovanja zavarenih konstrukcija, priznata od strane svetske zajednice za zavarivanje, koje je formulisao N.O. Okerblom, na infrastrukturnom i računarskom nivou.

2. Pristup N.O. Okerblom-a je dopunjen snažnim funkcionalnim i softverskim alatima za automatizovano projektovanje montažnih i zavarivačkih instalacija, postolja, provodnika itd.

3. Originalne metode i računarski softver, zasnovan na pojednostavljenim teorijama napona i deformacija usled zavarivanja, omogućavaju predviđanje prirode i veličine zaostalih deformacija usled zavarivanja dovoljnim za tačnost inženjerske prakse, uključujući i efekat pričvršćivanja na tehnološkoj opremi.

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