MODELING of WELDING SEAM SEQUENCES

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ABSTRACT

This paper explores simulation techniques for prognosis residual strains of welded structures taking into account welding seam sequences. Simplified approaches of welding stress and strain theories were used and implemented on SKIF-family supercomputers. The elaborated program options allow to apply the fictitious shrinkage forces to the weld models of arbitrary space location. The results of the experimental computational verification of the proposed approaches are presented, welded structures models of complicated design being used. The obtained results meet good agreement with data obtained in the production processes and special literature.

INTRODUCTION

According to international conferences materials connected with the basic directions of welding and related processes it is necessary to find the new ways of competitive welding structures creation [1]. Modeling of the basic stages of welding structures life circle which includes an interaction between the welding joints and the whole articles inner stress states from one side and outer dynamic loads from the other side can add a new quality to the welded structure elaboration processes. Namely at the design and construction stages basic resource indices and compatibility foundations together with up to 75% of all possible defects and faults are formed.

Welded structures constructive- technological design [5] as a part of CALS - technologies can not be thought without efficient welding residual stress and strain analysis. We proposed one of such calculation approach in [2, 3]. In this paper we are going to develop this residual welding strain calculation approach taking into account welding seam sequences.

In arc welding processes it is accepted to conditionally divide welds into short, middle and long [4, 5], that is based on practical data. In multipurpose commercial final element analysis systems of machine-building objects the differences between weld shrinkage influences on the whole stress-strain state of the construction caused by welds of different length are not practically taken into account. In that connection it seems to be expedient to develop approaches and corresponding models that provide the possibility to estimate the influence of non-relaxed stresses on the construction from the welds of different extent during static and dynamic strength calculations. In this article an attempt is made to advance in this direction using contemporary program tools deployed on SKIF-family supercomputers [11].

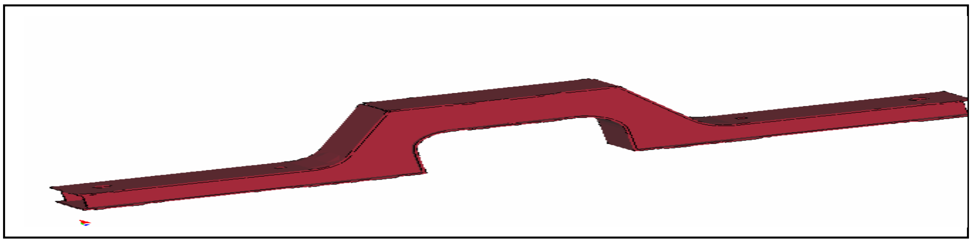
Known welding stress and strains theories are based on some assumptions and have therefore approximate character. In the software elaborated on their basis the main researches attention is concentrated on the thermo-deformational processes and phenomena located in welding joint and closed areas. We believe that using such approaches it is impossible to get the integral notion of the residual stresses and strains of the whole structure because the fixing conditions of separate parts and sub-assemblies and their mutual influence are not taken into account. The necessity of regarding these factors is confirmed by the cases of welded structures wrecking during exploitation when the causes of putting out of work are not evident, welded joints supposed to be made of high quality with following all the technological prescriptions.

The theory of welding deformations and stresses assumes that all welds are performed simultaneously [4]. However, modern point of welded structures design demand to change position of simultaneous welds creation [6].

Experimental Investigations

There are many welded structures consist of frames and box section like parts and assemblies in machine-building industries and enterprises.
Lets describe modeling technique by means of using real welded structures – box section longeron (Figure 1).

A common problem that appear in the welding fabrication of frames and longerons, a rather complex box-like vehicle structure, is propellant deformations. Longerons that have several meters length are of particular interest as they undergo these type of



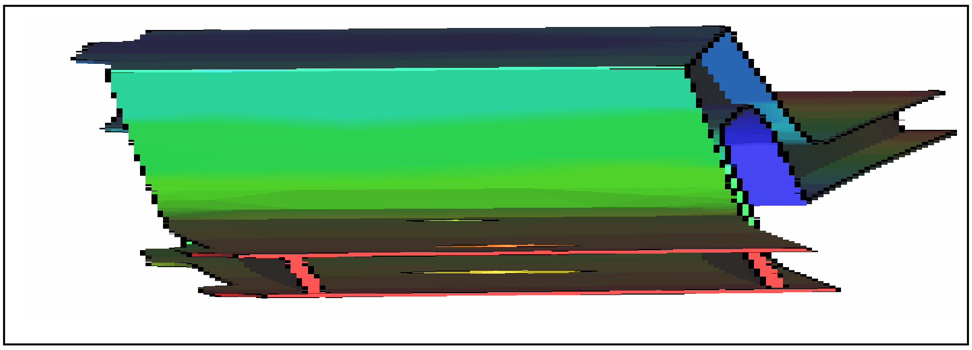


Figure 1. Propellant deformations of longerones

a) initial geometry (dimensions are 180x300x4000mm, wall thicknesses are 10 - 15 mm);
b) propellant deformation caused by the applied shrinkage forces

deformations more often (Figure 1). The extended welds that such structures appertain are recommended to be divided into a set of 250 - 300 mm long welds and then the question about the sequence of these welds deposition appears. In this paper two problems are studied. The conditions of the propellant deformations appearance dependent on the process related variables are investigated and the effect of the weld sequence on the chosen longerons result deformations in general is studied.

During the study three approaches were used. According to [6] the residual welding deformations were induced in the therma l- structural analysis by prescribing the initial high temperature to the weld. This approach was used to simulate the welds consequent deposition as the next weld was “laid” after the previous had completely cooled down to the room temperature. Then the embedded in LS-DYNA package Goldak moving heat source with chosen heat input and velocity moved along the joints [9]. And at last shrinkage forces method was used [2, 3] (Figure 3).

The values of the longerons deformations may be rather big (up to 20 mm) and the problem of the best technological scheme choice is to be solved [4]. Variants of the welding sequences for the 4000 mm length langerons were studied (Figure 3). Variants represented “through out” technique and variants represented back-step technique. The sub-variants in both groups differ by the choice of the weld order and direction.

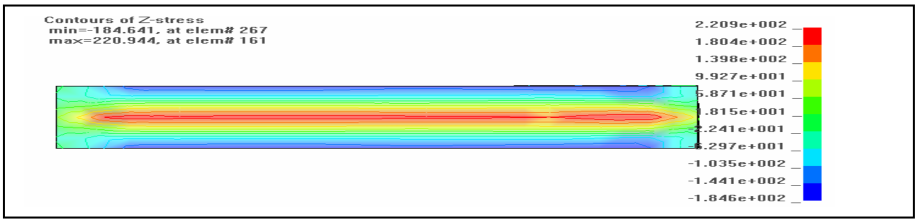
The results obtained by cooling weld ingots, caused by moving heat source and modeled by shrinkage forces method for the schemes a) - d) showed that the best variant concerning the residual strains is d), the worst is b). The approaches gave the same qualitative results that allowed to choose the best and the worst sequence of weld deposition on this structure. Three approaches though showed little differences in residual strains values differs in the obtained stress distributions and in the calculation time consuming. The elaborated shrinkage forces method shows the accuracy compared with that of obtained in the calculations with heat moving source but consumes less calculation time by several orders. The results shows where the adequacy between three approaches is and what the advantages of using shrinkage forces method are.

Results obtained with the use of the embedded in LS-DYNA package [10] moving heat source model assigned for thermal and coupled calculations connected with welding process modeling according to the Goldak work [9], slightly differ from that of [2]. It is accounted for as by the differences in two and three dimensional problem formulations, so by the differences in plate geometry and the used welding conditions. Numerical experiments showed that end effects can have diversities dependant on the dimensions, sides ratios, heat input and welding speed.

For example, for the transverse stresses at the plates ends it is common to have alternations of shrinking and stretching areas, the correlations of their magnitudes and quantities at the each end are defined by above mentioned parameters (Figure 2).

Obtained results for the end effects allow to make some suggestions about the beginning and the end of the weld distinguishing. Confined by the case of the thin plates it is necessary to make some preliminary remarks about stress-strain state occurred after they have been welded. It is considered that plate transverse stresses σ_{yy} behave with great variety. For example, when the length and the width of the plate differ more than three times and the plate according to [4] did not lost the stability the transverse stresses can be shrinking at the ends and stretching in the middle. In long plates transverse stresses σ_{yy} are low and can be found only at the ends in the case of high speed welding. When non-fixed short plates with a gap are welded, assuming the welding speed is low, the stretching transverse stresses are induced at the ends of the weld and shrinking transverse stresses in the middle of the weld [7]. Studied here cases (Figure 1) corresponds to the “basic” residual stresses distributions shown in figure 3.

While inserting information about the end effects and the differences between long and short welds into the program options, an attempt was made to insert the differences in the residual stresses values of the beginning and the end of the weld for the plates



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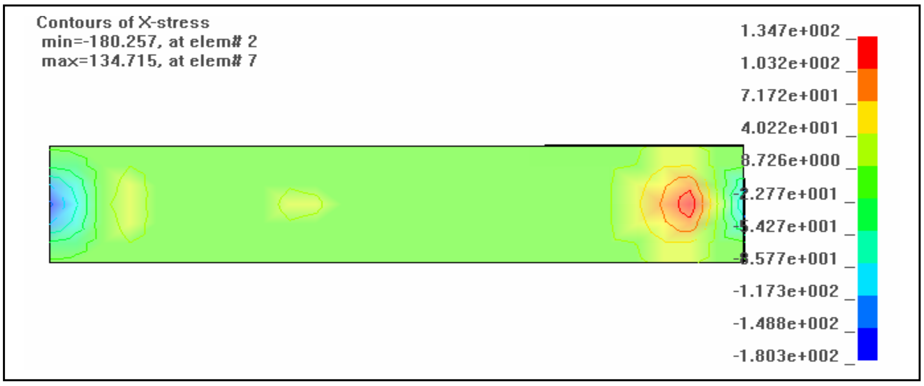

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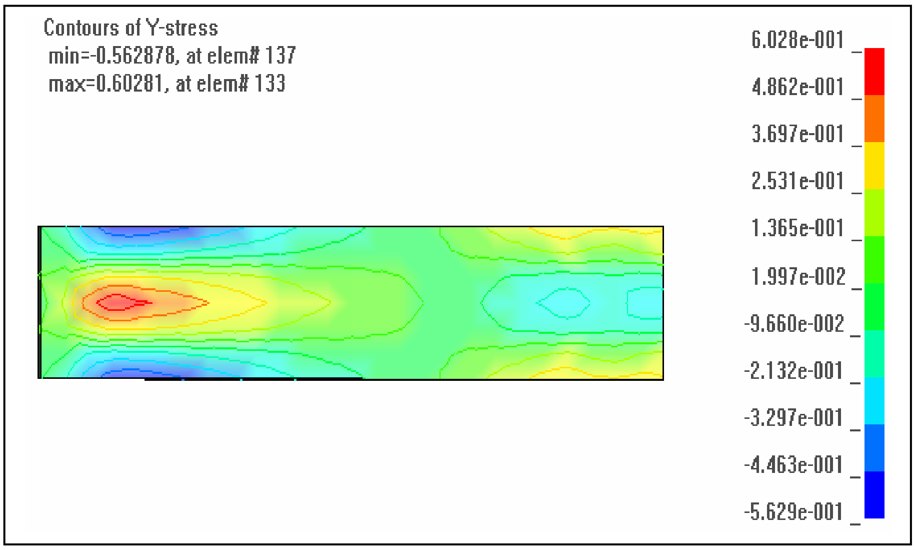

c)

Figure 2. σ_{xx}, σ_{yy} и σ_{zz} stresses distributions for the 260x46x12mm plate

a) longitudinal stresses;
b) transversal stresses;
c) through thickness stresses

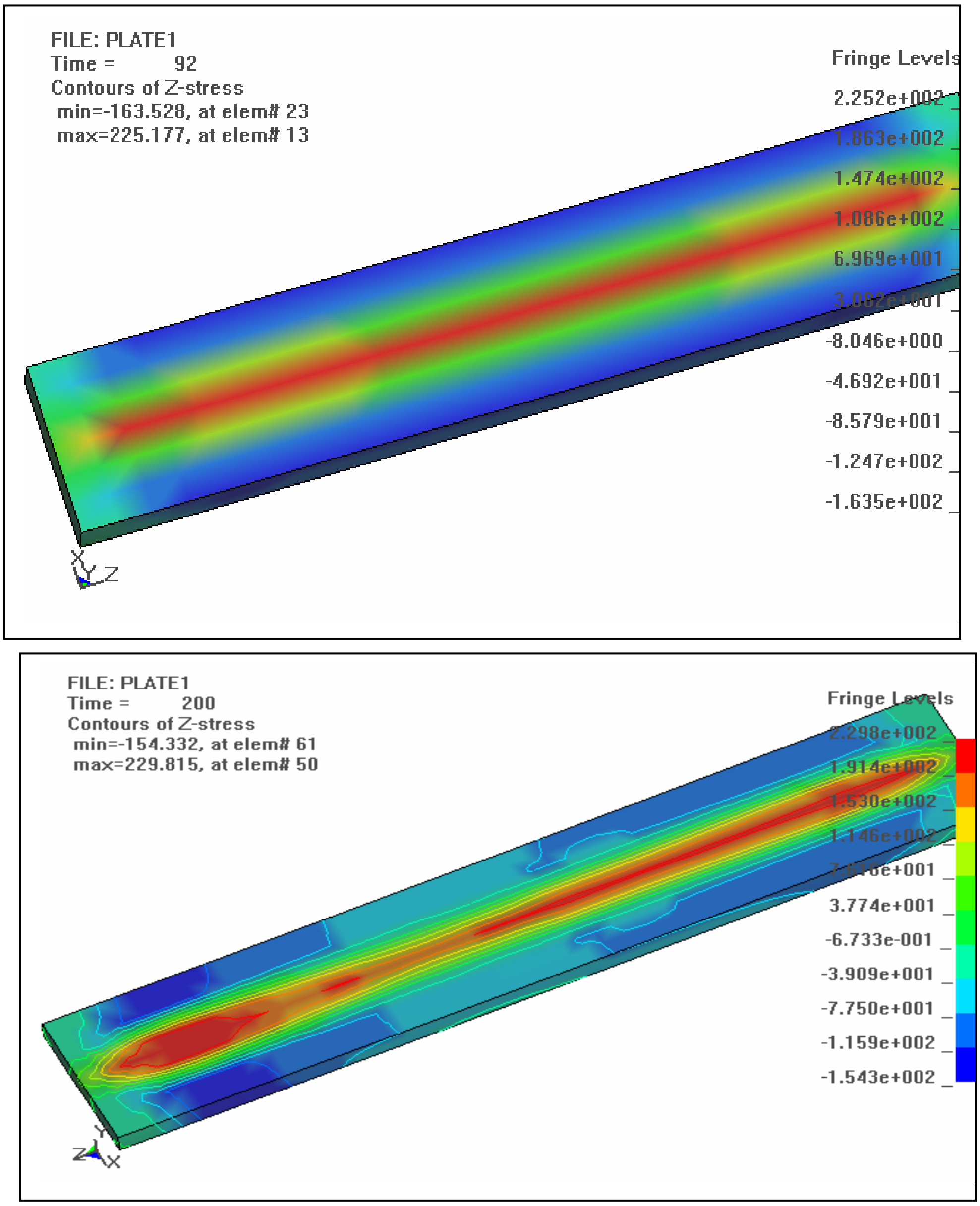

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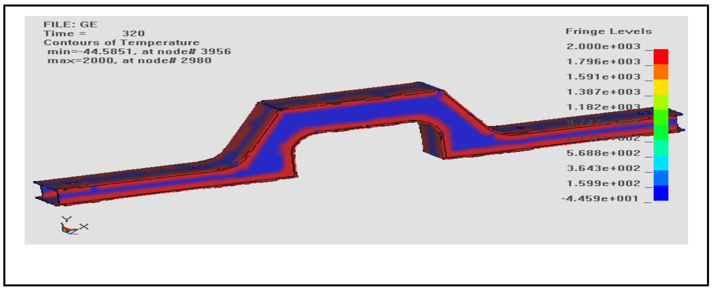
Figure 3. The differences between short and long welds
in longitudinal stresses distributions
a) σ_{yy} on the 260x46x12 mm plate;
b) σ_{yy} on the 520x46x12 mm plate



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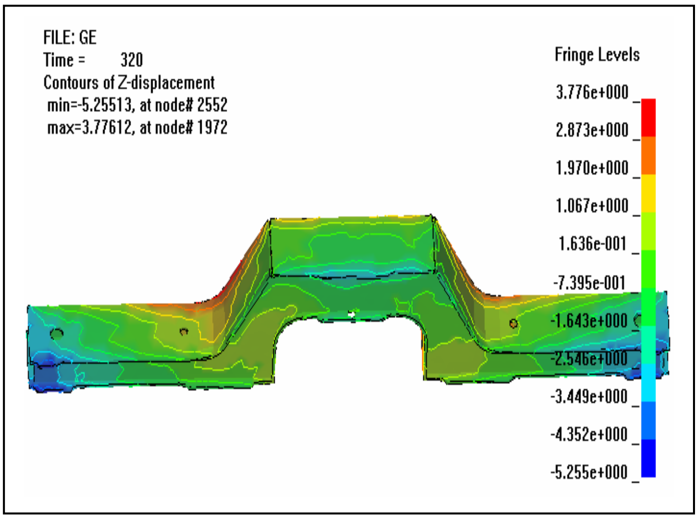

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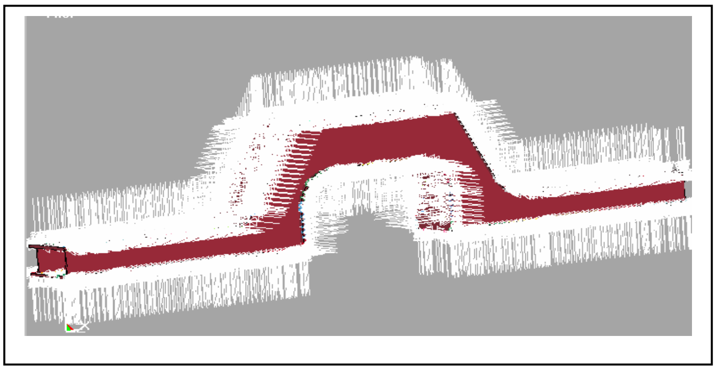
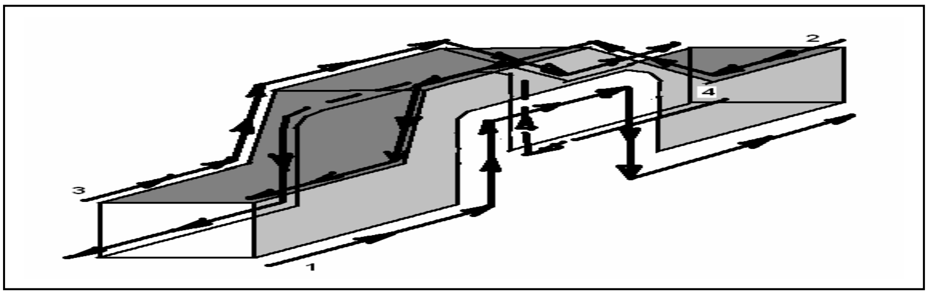


c)

Figure 4. Input of different approaches
a) initial finite element longeron model with welds;
b) residual strain distribution obtained by cooling ingot;
c) shrinkage forces method load scheme



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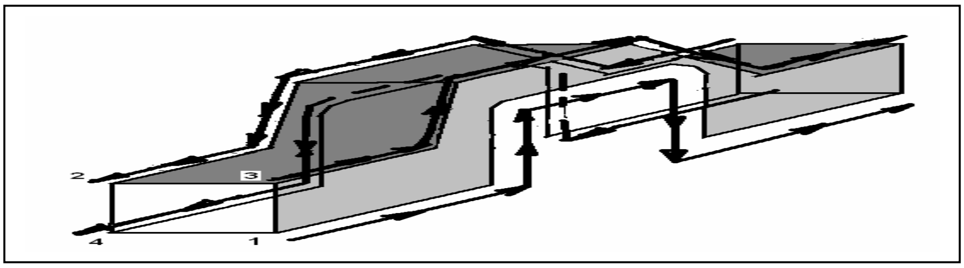

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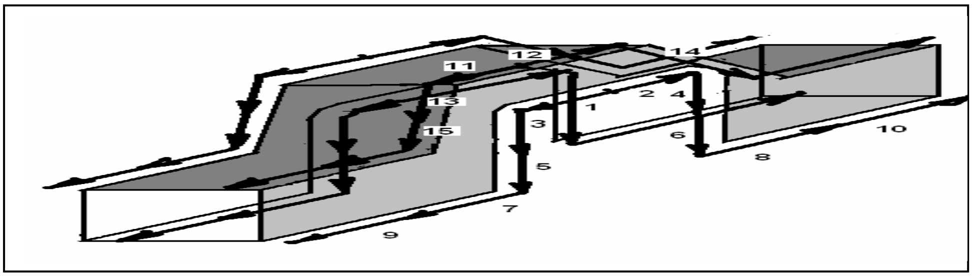

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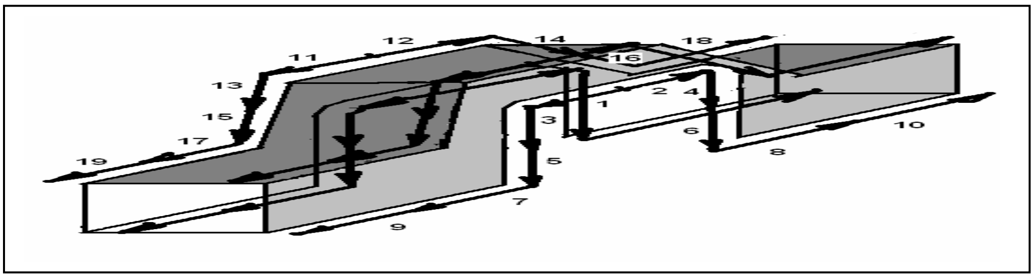
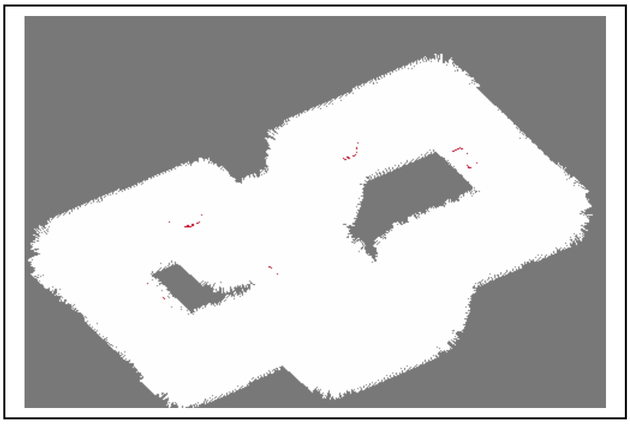
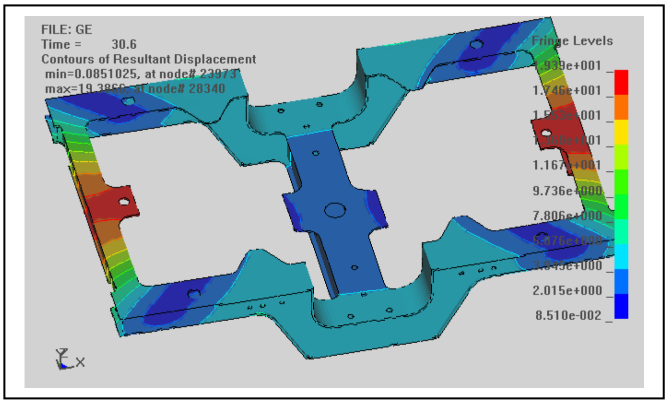


d)

Figure 5. Variants of welding sequences
a), b) “through out” technique;
c), d) back-step technique



a)



b)

Figure 6. Model od complex welded structure
a) shrinkige force loading along welds;
b) resultant displacement after welding

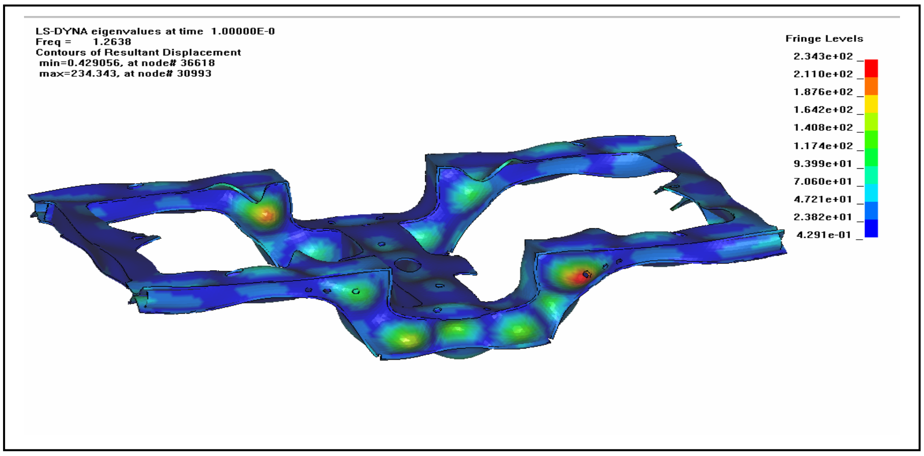


Figure 7. Modal analisys results of complex welded structure

Summary and Conclusions

The dependences of shrinkage forces values distributions alongside the welds are determined. The beginning and the end of the welds are marked out and long and short welds are also distinguished.

Further investigations, practical appliance of the mentioned program, methodical and technical means will allow to correct, approve or disapprove this paper suggestions. Author will admit with acknowledgments any remarks and proposals on the theme and also answer to the mutually advantageous collaboration proposals on the welded structures constructive technological design problems with the use of the possibilities of SKIF family supercomputers [11]. To our mind one of the perspective research direction is modal complex welded structures analysis (Figure 7) taking into account welding seam sequences.

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