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# Development of simulation system JWELD for assembly deformation of welded structures†

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**KEY WORDS:** (Welding Deformation) (Assembly Deformation) (Simulation) (Welded Structures)

## 1. Introduction

Welded structures are generally assembled by multiply stages such as the weld line fitting stage, tack welding stage and final welding stage. To predict the deformation of welded structures produced at all assembly stages, fast and accurate simulation software is required by industrial users. Furthermore, if a data base of welding inherent deformation for basic welded joints is created, the welding deformation produced in a welded structure can be easily predicted at the design stage. Then, various countermeasures before manufacturing welding structures can be investigated by simulation.

To answer the requests from industrial users, a dedicated simulation system JWELD is developed based on JWRIAN, which is a very fast elastic FEM solver using inherent strain theory [1] and interface elements arranged between welded parts [2]. A data base for welding inherent strain is also included in the system. With the aid of JWELD, the assemble deformation for large scale welded structures with many weld lines can be predicted within several ten minutes. The effect of assembly sequences of multiply weld lines on welding deformation can be easily visualized by this system.

## 2. Development of Simulation System JWELD

**Figure 1** shows a proposed new flow to use the simulation technology for welded structures from design stage to welding assembly stage. If the welding deformation produced in a welded structure can be simulated before production, the time and the cost of experiments (old approach) will be greatly saved.

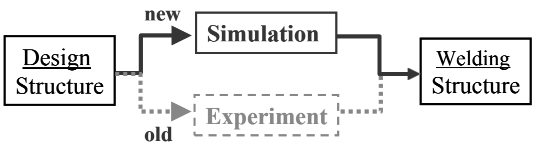


**Fig. 1** Simulation stage for a welded structure

Comparing with other commercial CAE software which is mainly applied to predict the welding deformation for a certain welded joint, JWELD is a dedicated and integrated simulation system which is available not only for a simple welded joint but also welded structures built by multiply weld lines and various welded joints. This system consists of a dedicated FEM solver JWELD, a program JWDB for management and prediction of inherent deformation data base, and a pre-post processor JVSION [3] as shown in **Fig. 2**.

The pre-processor JVISION/Pre has an interface to import the geometry of a welded structure which has been used for strength analysis of various commercial FEM solvers such as NASTRAN, LS-DYNA, IDEAS in current version and CAD data directly in the next version. The multiply weld lines can be automatically identified if a pair of parts or an element group or a node group is defined. The deformation of each weld line consists of the deformation due to weld line fitting, tack welding and final welding. The assembly sequences can be easily defined in a form of table. The system supplies a reference data base for several basic welded joints. Users can also build their own data base using data base creating program JWDB.

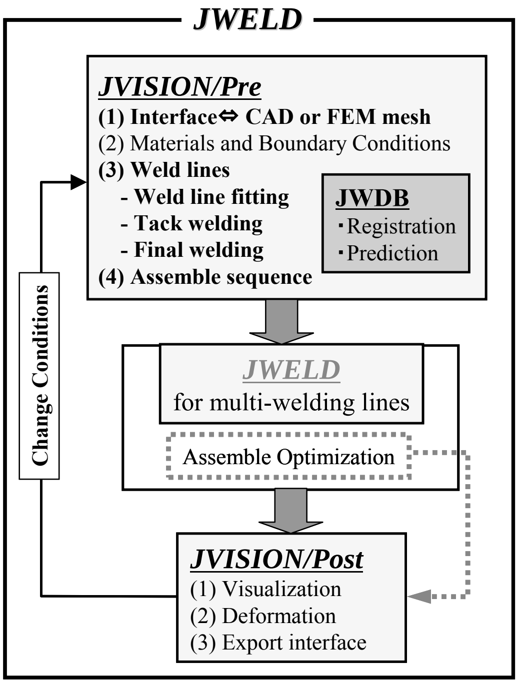


**Fig. 2** Schematic showing of simulation system JWELD

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If a geometry model of a welded structure is built and the assembly sequences are given, the deformation due to weld line fitting, tack welding and final welding can be predicted by FEM solver JWELD within very short CPU time. Furthermore, in order to control the deformation, the optimization of assemble sequences is being developed and will be released for next version.

The post processor JVISION/Post can directly show the deformation produced by each weld line. The geometry with assembly welding deformation can be exported for the other purposes of simulation.

## 3. Verification of Simulation System JWELD

To help users to apply this simulation system, the welding deformation in basic welded joints much be verified firstly. **Figure 3** shows a single-sided fillet joint and welding deformation computed by JWELD. The arc welding conditions and inherent deformation [4] for this fillet welded joint are shown in **Table 1**.

**Table 1** Arc welding conditions and inherent deformation

| I (A) | U (V) | v (mm/s) | $\delta_x$ [mm] | $\delta_y$ [mm] | $\theta_x$ [rad] | $\theta_y$ [rad] |
|---|---|---|---|---|---|---|
| 180 | 24.0 | 5.0 | 0.061 | 0.11 | 0.00 | 0.021 |

The single sided weld line of fillet joint is located on the right side of flange. Therefore, the deflection on the right side of flange is larger than that on the left side.

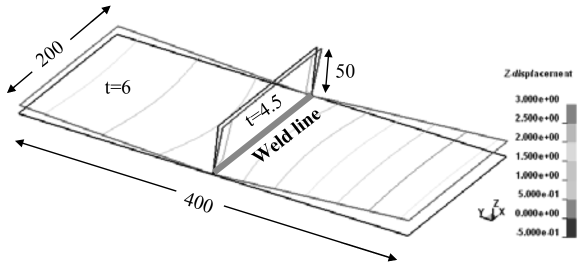


**Fig. 3** Deformation due to a single-sided fillet welding

**Figure 4** shows the welding deformation of H type section of fillet welds due to a single-sided weld line (W1) between the lower flange (part-1/t=6) and web (part-2/t=4.5). If two tack welds between web and upper flange (part-3/t=6), the angular distortion due to the weld line (W1) will make the upper flange deform following the web.

If there are no any tack welds between the web and upper flange, the gap and misalignment at the interface will produced. If correction of the gap and misalignment in both transverse direction and normal direction are modeled by the interface element formulation [2] between the upper flange and the web, the upper flange will deform only in y direction and z direction as shown in **Fig. 5** by two arrows.

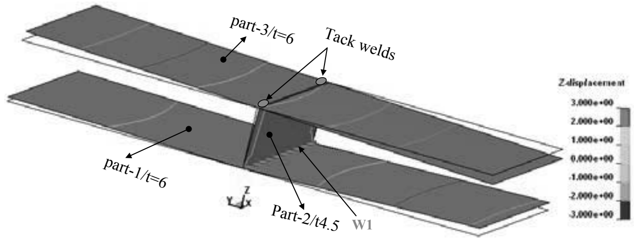


**Fig. 4** Deformation due to a single-sided fillet welding for a H-section joint

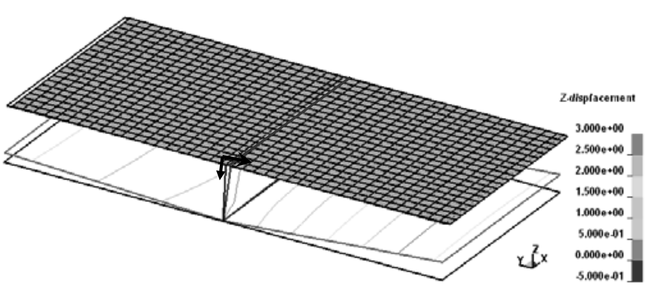


**Fig. 5** Correction deformation of upper flange modeled by the interface element formulation

## 4. Applications of Simulation System JWELD

(1) Welding assembly deformation in a grid structure

**Figure 6** shows a long grid structure which has ten parts and nine welding lines. The welding assembly sequences are also shown in Fig.6. The grid made from steel SS410 is assembled by arc welding process. The welding current, voltage and welding velocity are 400A, 20V, 10mm/sec for three butt weld lines (W1, W2 and W3) and 250A, 25V, 10mm/sec for fillet weld lines (W4, W5) and (W6, W7, W8, W9), respectively. The welding lines W4, W5 are double sided fillet welds and weld lines W6, W7, W8, W9 are single sided fillet welds. The inherent deformations of these weld lines are predicted using a data base creating program JWDB. **Figure 7** shows the computed final deformation due to sequential assembly welding from W1 to W9.

(2) Welding assemble deformation in a train car model

**Figure 8** shows a simplified FEM model [5] of a train car structure for the computation of welding deformation. The details are neglected because the limitation of space.

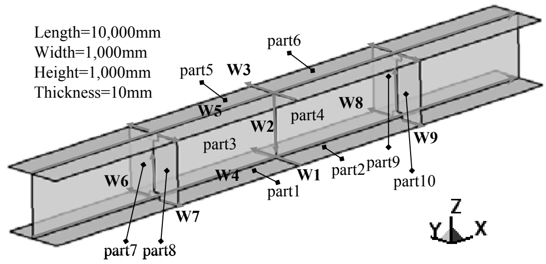


**Fig. 6** Gird model for computation of welding deformation

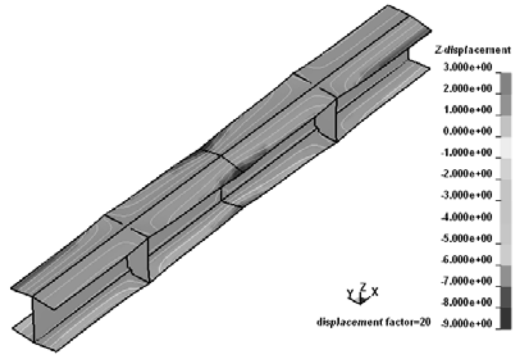


**Fig. 7** Computed welding deformation of gird model

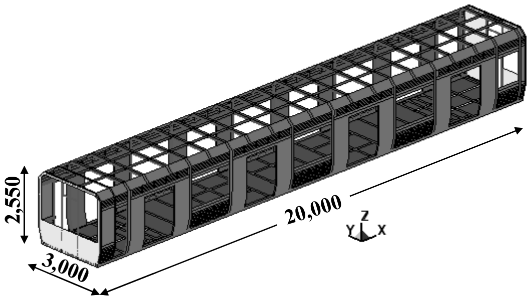


**Fig. 8** Train car model for computation of welding deformation

## 5. Summary

(1) Integrated simulation system JWELD was developed for industrial users.

(2) The validity of this system was verified by basic welded joint models and structural models.

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