Continuous simulations from Resistance Spot Welding Process to Joint Strength

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1 Abstract

Resistance Spot Welding (RSW) is a low cost and efficient method compared with rivet and adhesive. RSW is also easily automatized and can make robust joints. Therefore, it has been widely used in assembling vehicle bodies of thin metal plates.

These days, the use of Ultra High Strength steel and Aluminum plates increases in vehicle structures, so there is necessity to study stable welding conditions and predict the welding effect, especially the effect of Heat Affected Zone (HAZ) on these materials.

Despite of the simple principle of the RSW process, the complicated physical phenomena occur sequentially. Plates are pressed with spot welding electrodes and melted by the Joule heat generation of the electric current resistance. Finally material property gradually changes due to phase transformation depending on their temperature history, especially on cooling speed.

The temperature distribution over than melting temperature or the phase transformation temperature can be used to evaluate the nugget size and phase transformation zone. So it is important to take into account these sequential and multiple physical results in order to evaluate joint stiffness and strength.

With the aid of enhanced multi-physics features of LS-DYNA, we performed the continuous simulations from resistance spot welding process to the joint strength considering the effects of phase transformation occurred during cooling.

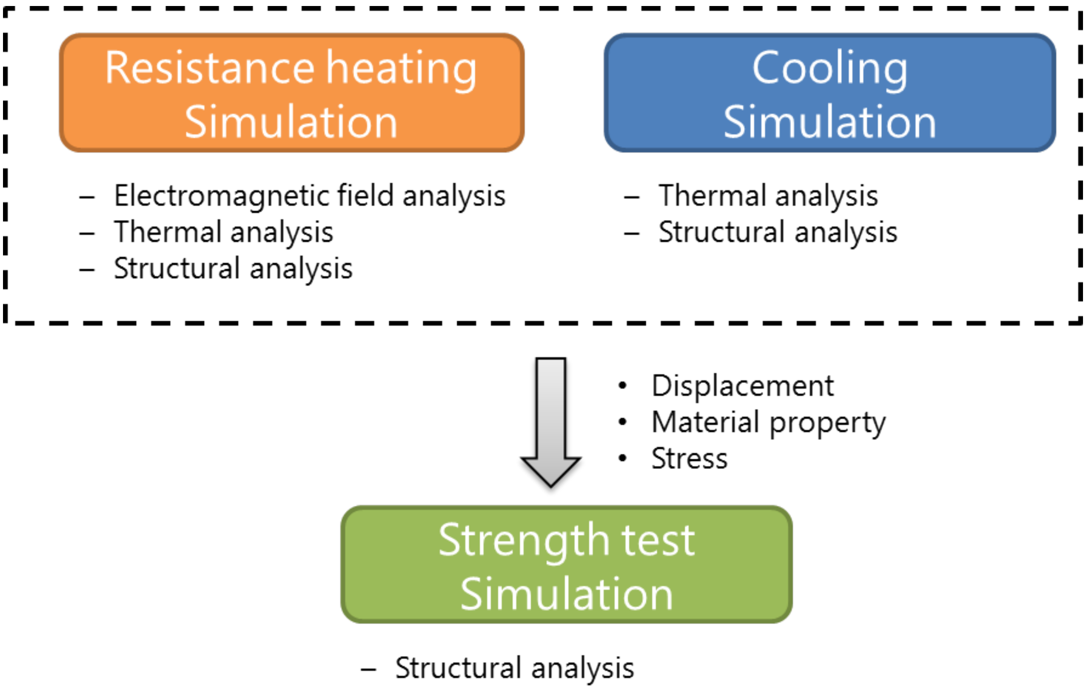

Fig.1: Chained Processes of Simulations

2 Resistance heat and cooling analysis

2.1 Model Specification

Fig.2 shows RSW simulation model for resistance heat and cooling analysis. Mechanical-Eletro Magnetic-Thermal coupling analysis is performed using LS-DYNA. 2.5[kN] force and 5.0[kA] current is applied to two electrodes. These electrodes and metal plates contact mechanically, electrically, and thermally each other. Electrical current is supplied in first 0.35[sec]. Mechanical force is always applied in the total phenomena time 3.0[sec]. Thermal convection to atmosphere is taken into account. These sequential phenomena are shown in Fig.3.

Material properties of two metal plates are shown in Table.1 and Fig 4. These have temperature-dependent thermal and electrical properties. *MAT_UHS (*MAT_244) is applied to them in order to calculate phase transformation. Initially they consists of 2% Austenite and 98% Ferrite. Table.2 shows element component in the alloy defined in MAT_244. This composition is same in the upper and lower plates.

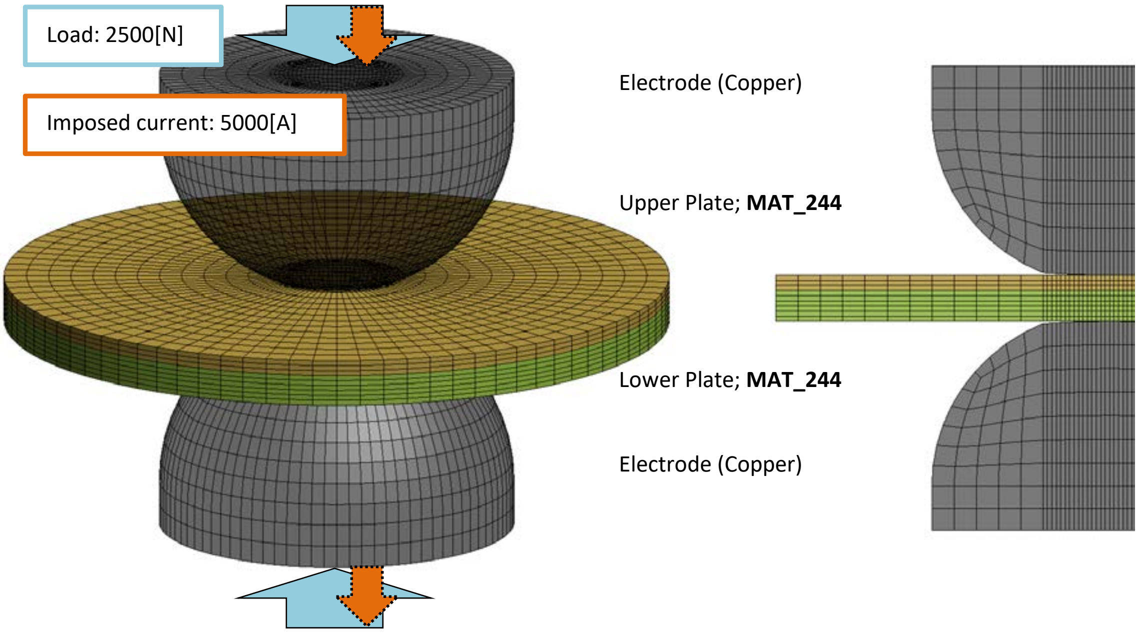

Fig.2: Simulation model of RSW

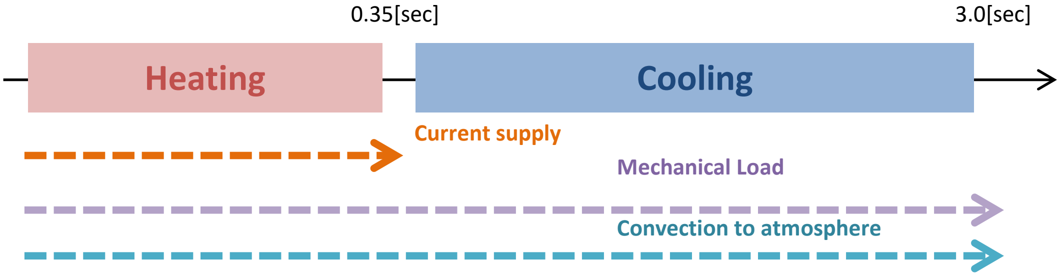

Fig.3: Fig.3 Phenomenon in RSW simulation

	Name(JIS)	Young Modulus	Yield Stress (at 293[K])	Thickness
Upper Plate	JSC270E	210.0[GPa]	190.0[MPa]	0.7[mm]
Lower Plate	JSC590	210.0[GPa]	390.0[MPa]	1.4[mm]

Table 1: Plates material properties

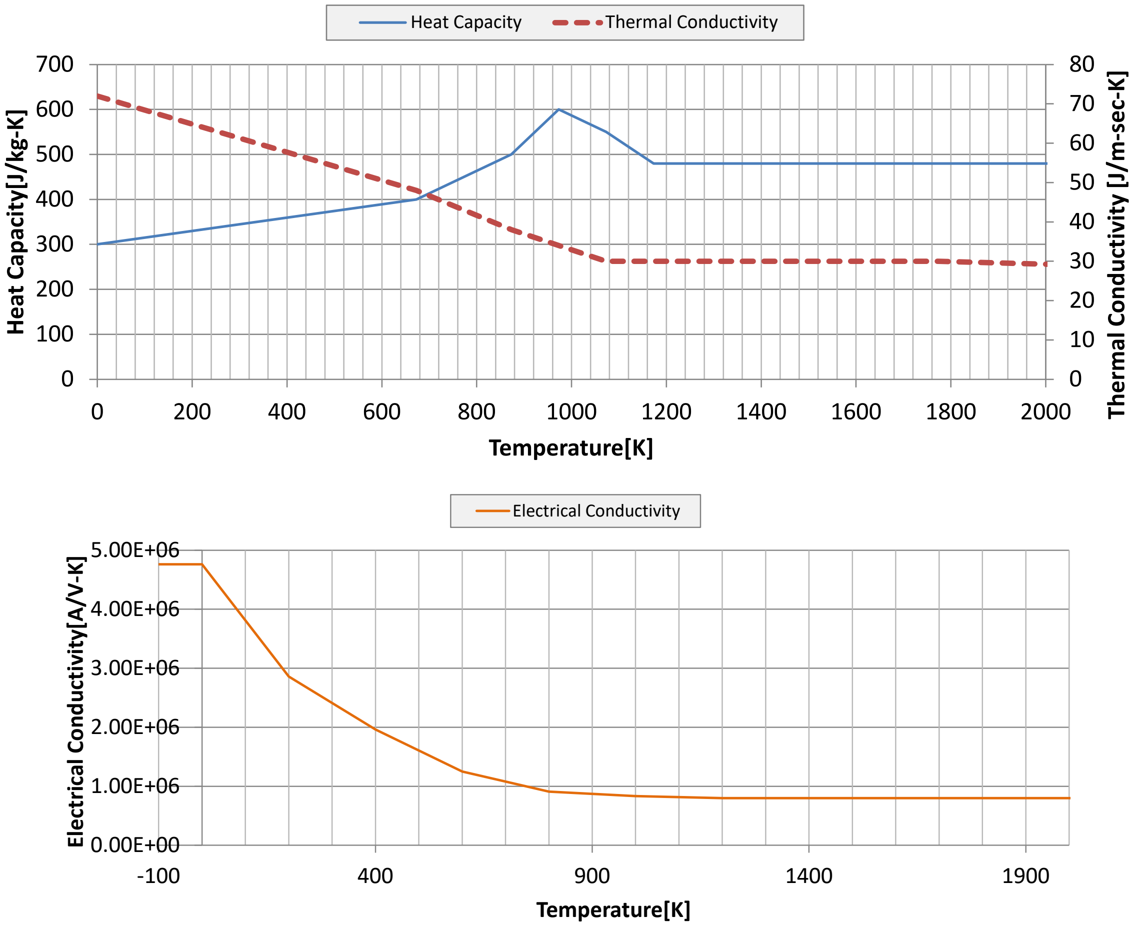

Fig.4: Temperature-dependent properties

Component	[weight%]
Fe	98.0
B	0.003
C	0.23
Cr	0.211
Mn	1.25
Si	0.29
P	0.013

Table 2: Element component of alloy for MAT_244

2.2 Temperature and phase transformation

Calculated temperature distributions are shown in Fig.5. Each plate is gradually heated by Joule heat until 0.300[sec]. There are 2 types of Joule heat. The first is one by electrical resistance of plates, and the second is one by contact resistance. Effect of contact resistance can be seen in temperature distribution at 0.100[sec], highest temperature is widely spread especially in the interface between two plates. This is a typical phenomenon in RSW heating. LS-DYNA can realize it by definition of *EM_CONTACT_RESISTANCE. Nugget area can be estimated using Fig.6. It shows temperature distribution over than melting temperature of iron; 1800[K].

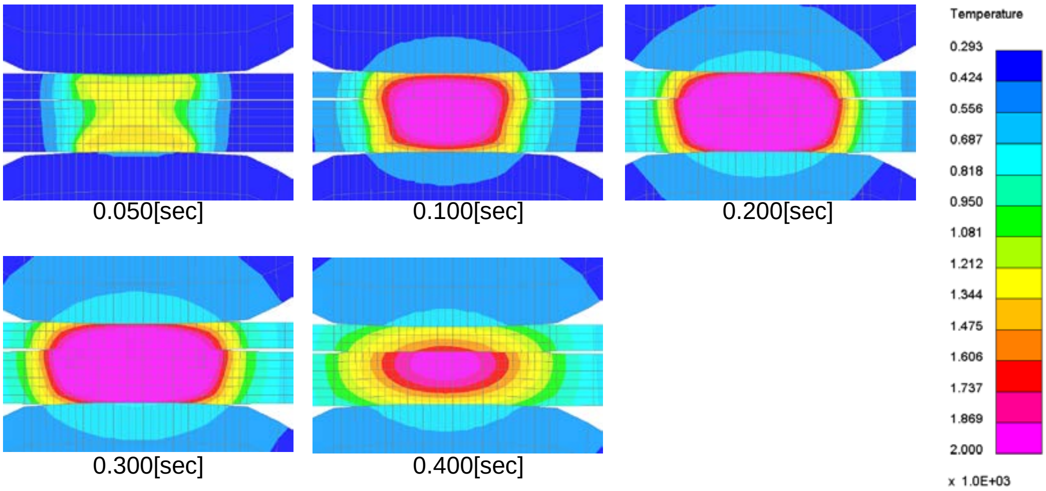

Fig.5: Temperature distribution [K]

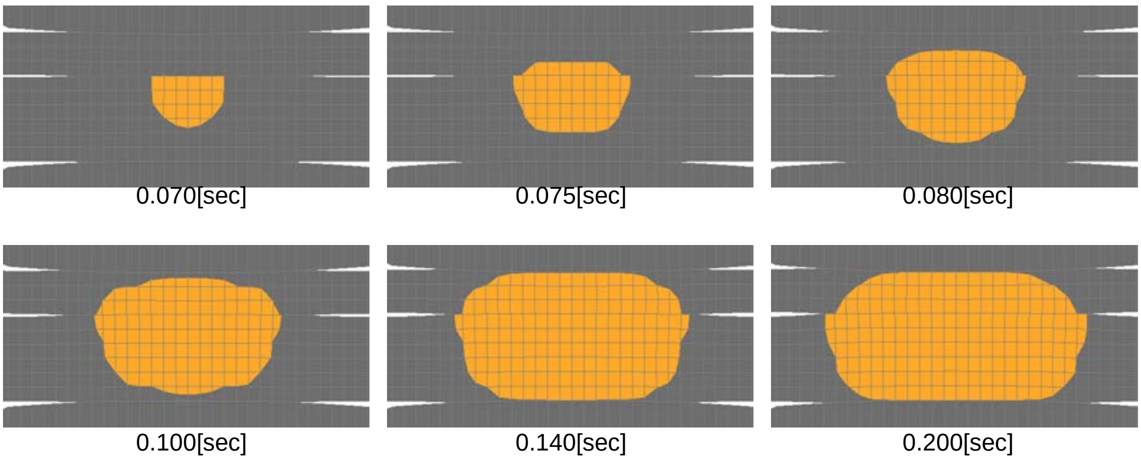

Fig.6: Temperature distribution over than 1800[K]

Fig.7-9 shows fraction distribution of Austenite, Ferrite and Martensite each. When Austenite fraction shows 1.0 in a solid, it means the solid consists of 100% Austenite. Austenite distribution is gradually spread into outer area, coincidently originally exited Ferrite diapers until 0.500[sec]. At about 0.930[sec], spread Austenite is rapidly transformed into Martensite.

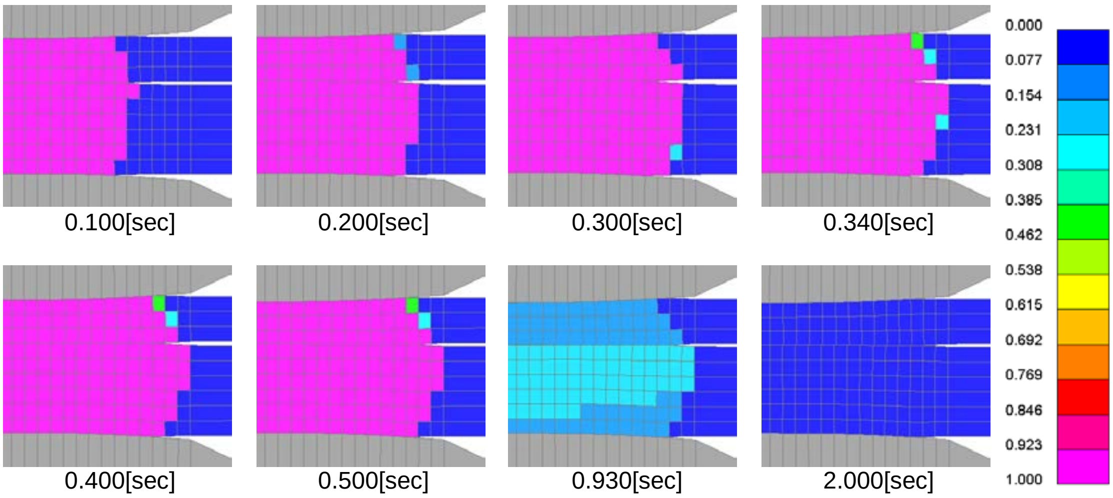

Fig.7: Austenite fraction distribution

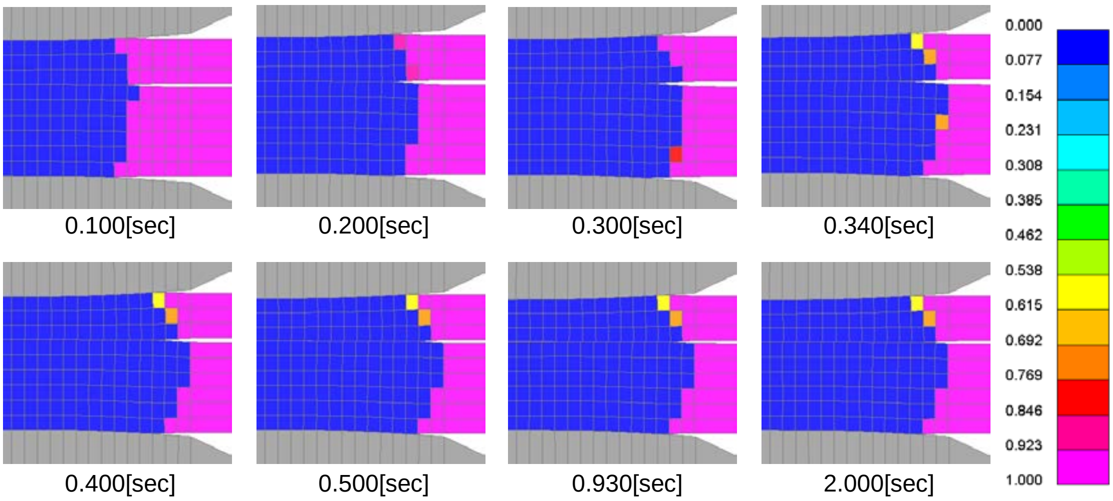

Fig.8: Ferrite fraction distribution

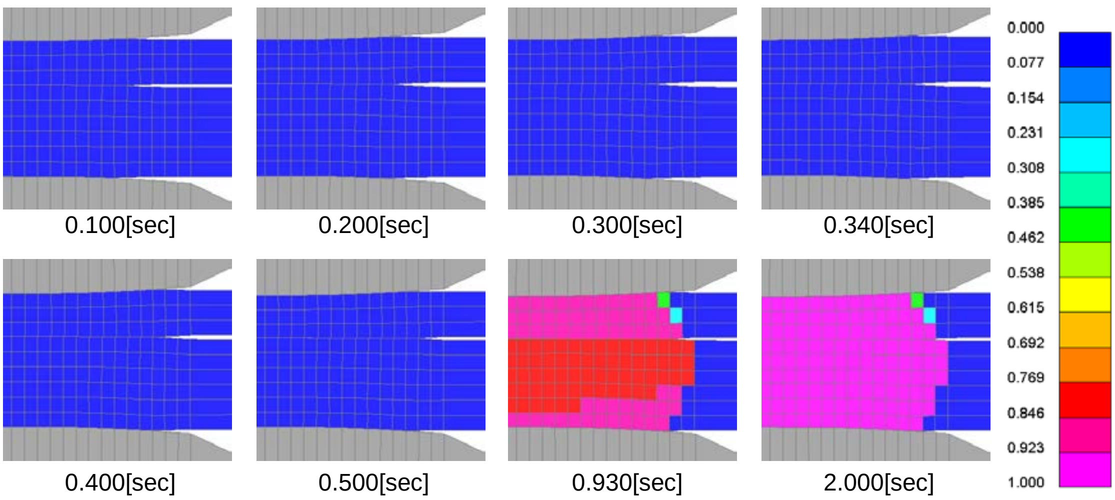

Fig.9: Martensite fraction distribution

In RSW heating and cooling process, temperature changes very rapidly. Fig.10. shows history of temperature and its rate at 3 nodes. Each temperature goes over melting temperature 1800[K] within 0.40[sec]. During cooling, temperature rate goes under -10000[K/sec].

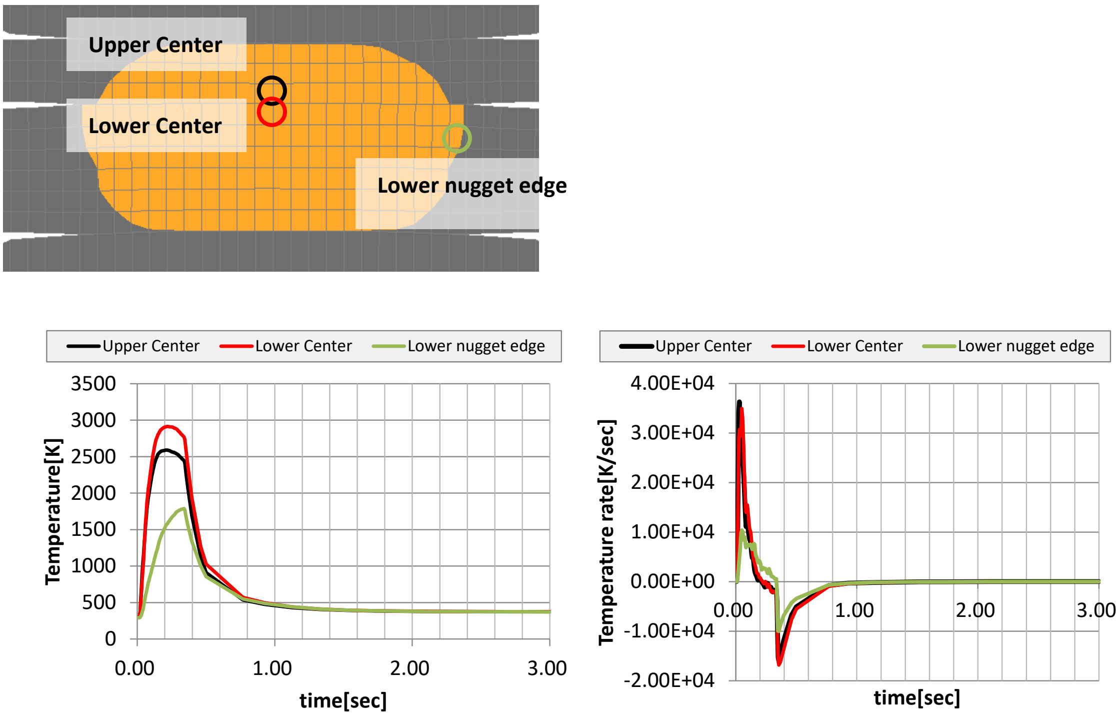

Fig.10: Temperature and temperature rate history

3 Specimen strength test analyses

Strength test analyses can be done by inheriting material characteristics using dynain file. In addition to MAT_244 properties, *MAT_ADD_EROSION is necessary.

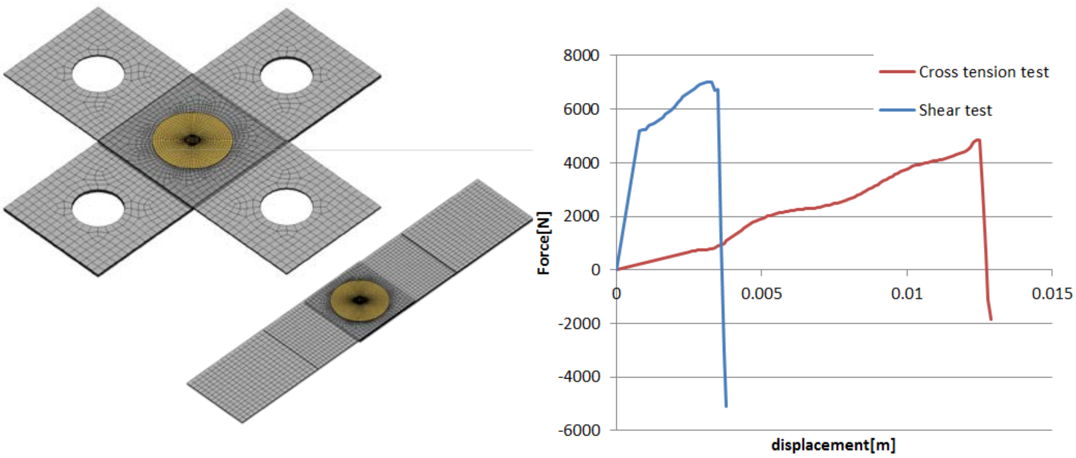

Fig.11: Coupon spesimen test analyses

4 Summary

In this work, with enhanced multi-physics features of LS-DYNA, RSW process simulation can be performed. We are going to keep researching mechanism of RSW and LS-DYNA features in order to estimate RSW stiffness and strength in CAE.

5 References

[1] P. Akerstrom and M. Oldenburg, “Austenite Decomposition During Press hardening of a Boron Steel – Computer Simulation and Test”, Journal of Material processing technology, 174 (2006), pp399-406.Name, Abbreviation of first name: "publication", issue, year, pages

[2] Numerical and experimental study on nugget formation in resistance spot welding for three pieces of high strength steel sheets “, Journal of Materials Processing Technology 210 2045-2052