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Numerical Modeling of Resistance Welding Process in Joining of Thermoplastic Composite Materials Using Comsol Multiphysics

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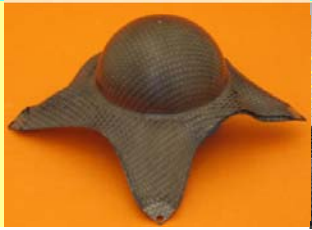
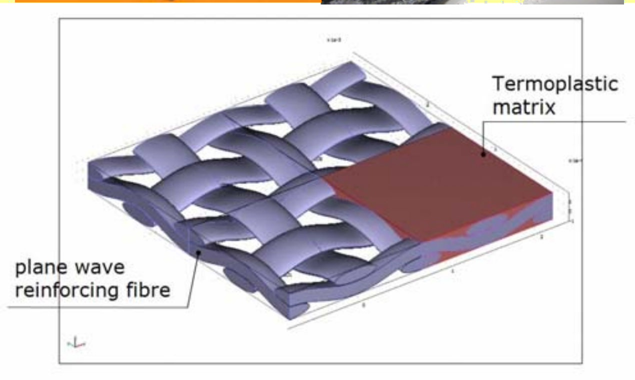
OBJECTIVE

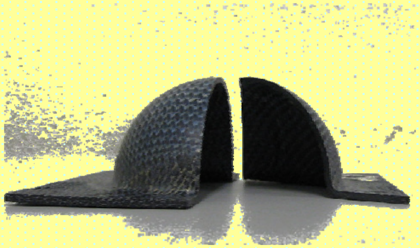
To estimate the mean parameters influence and verify the **joining feasibility** in the **resistance welding** of two thermoplastic composite (TPC) parts

THE THERMOPLASTIC COMPOSITES (TPC)




Are made of reinforced fibres in a thermoplastic resin






ADVANTAGES:

I. *the TPC in laminate form can be re-heating and successively formed*
II. *the resin in the TPC laminate can be re-heating and utilized to joint more TPC parts*

DISADVANTAGE:

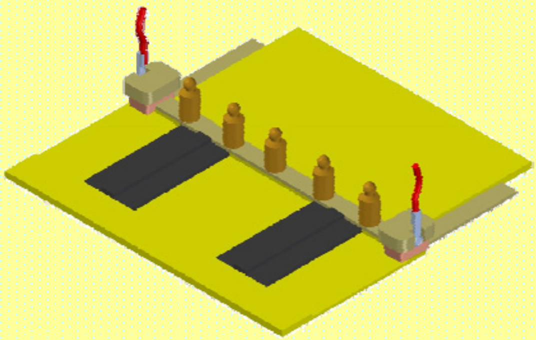
I. *relatively low glass transaction temperature for thermoplastic resins*
II. *the friction in the fibres reduce the layers sliding consequently the TPC formability to any part shapes*

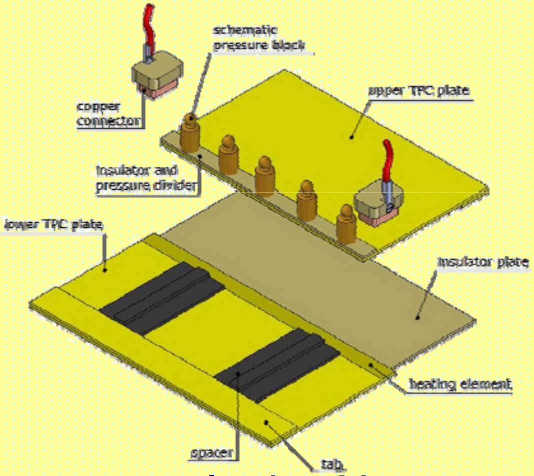
JOINING THECNOLOGY IN TPC PARTS

The fusion-bonding technology for the TPC parts take advantage from the repeatability melting proces for the resin phase

a.	*INDUCTION WELDING (IW)*	-No limit in the overlapping length -Problem with the **magnetic field** interaction in the surround of the joining device -Possible contamination dependently by the conductive media
b.	*RESISTANCE WELDING (RW)*	-Easy and fast to realize -Limitation in the overlapping joint length -Possible contamination dependently by the conductive media
c.	*ULTRASONIC WELDING (UW)*	-No need conductive media - Risk of fibre disruption at the interface under the large deformation
d.	*ADHESIVE BONDING (AB)*	- Thermoplastic composite surfaces are usually too low superficial energy - Cure time

The Joule effect in a conductive media heating up the thermoplastic resin above the matrix melting temperature



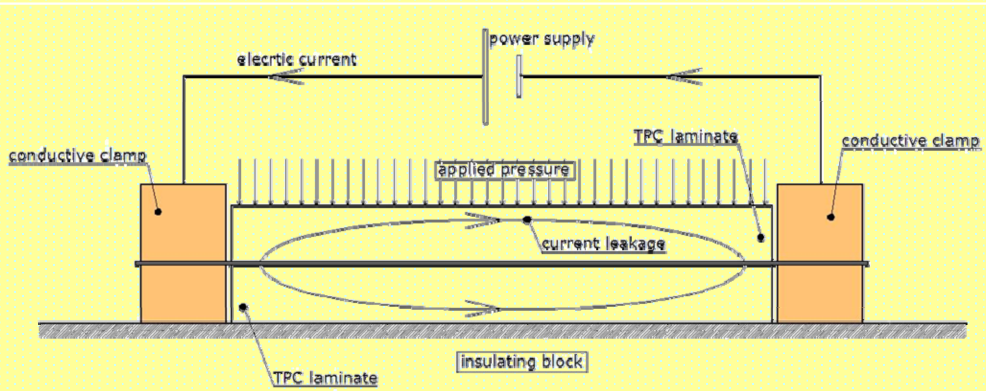


CONDUCTIVE MEDIA

a. **METAL MESH** – lack of homogeneity

b. **CARBON FIBER** – homogeneity in CFR THERMOPLASTIC composite materials

TPC RESISTANCE WELDING PROCESS: THE PARAMETERS



INFLUENCING PARAMETERS

- **TIME PROCESS**
- **ELECTRICAL POWER DENSITY LEVEL**
- **EXTERNAL APPLIED LOAD**

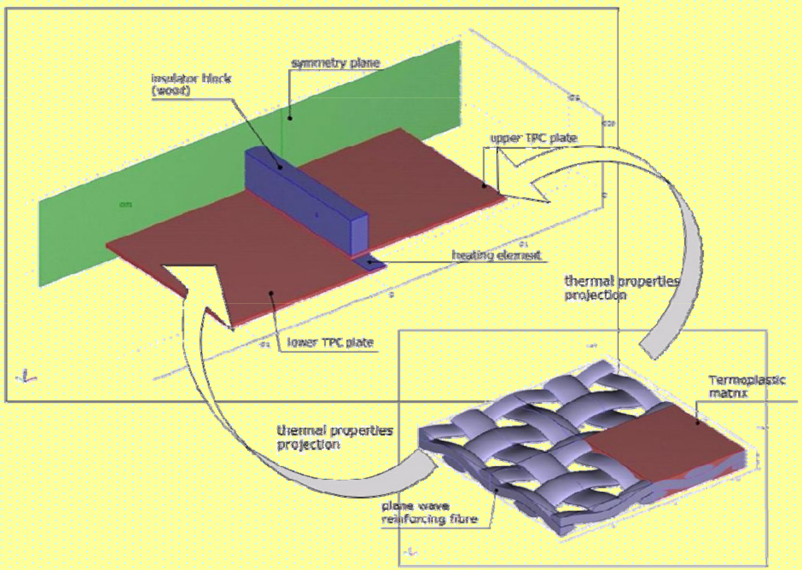
TPC RESISTANCE WELDING PROCESS: THE NUMERICAL MODEL

THERMAL CONDUCTIVITY TPC LAMINATE MODEL

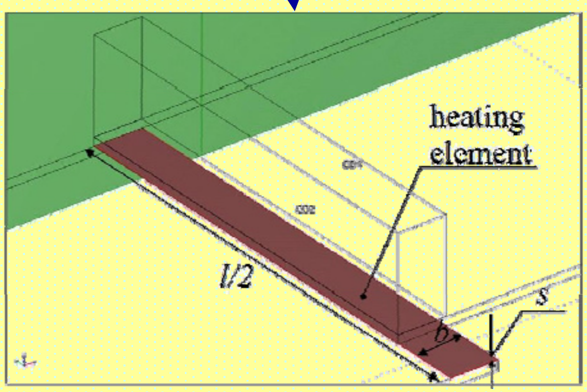
+

JOULE INDUCING HEATING

$$\dot{Q} = \frac{\left(R \cdot I^2\right)}{b \cdot l \cdot s}$$



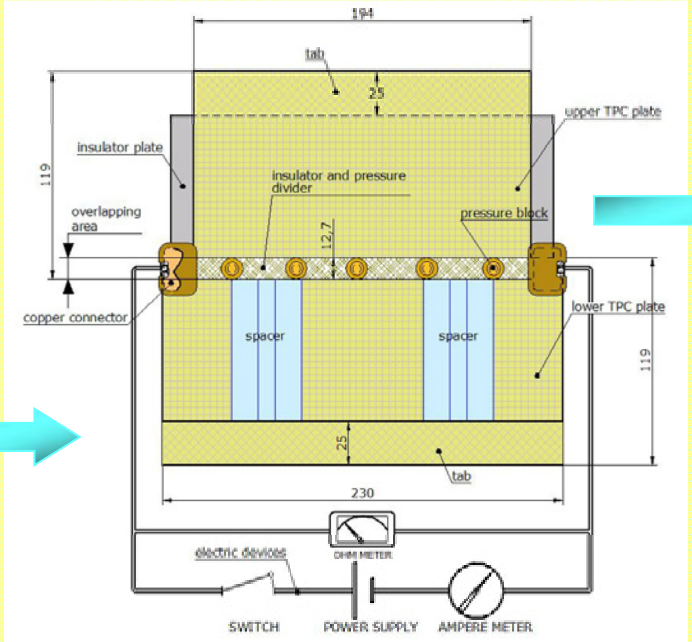
RW PROCESS SIMULATION



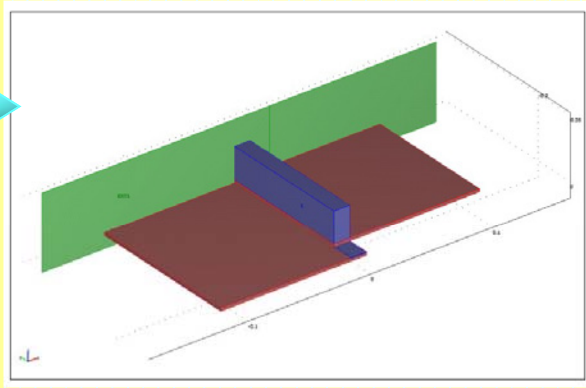
HEAT TRANSFER PROBLEM

The model geometry was build up on the experimental configuration employed to test the RW process on TPC laminate

EXPERIMENTAL CONFIGURATION



GEOMETRICAL DIMENSIONS



NUMERICAL MODEL

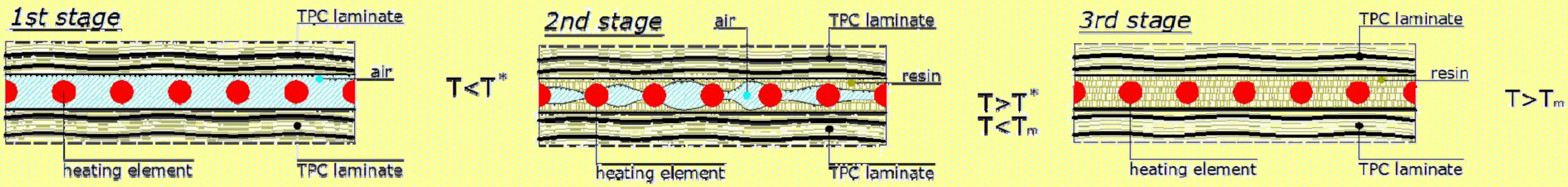
TPC RESISTANCE WELDING PROCESS: THE SIMULATION PARAMETERS

- parametric analysis was carried out using different electric power density coupled with longer or shorter time process

- 2.1 mm thick eight plies polyphenylene sulphide (PPS) reinforced by glass plane wave fabric were simulated using the parameters of the experimental investigation

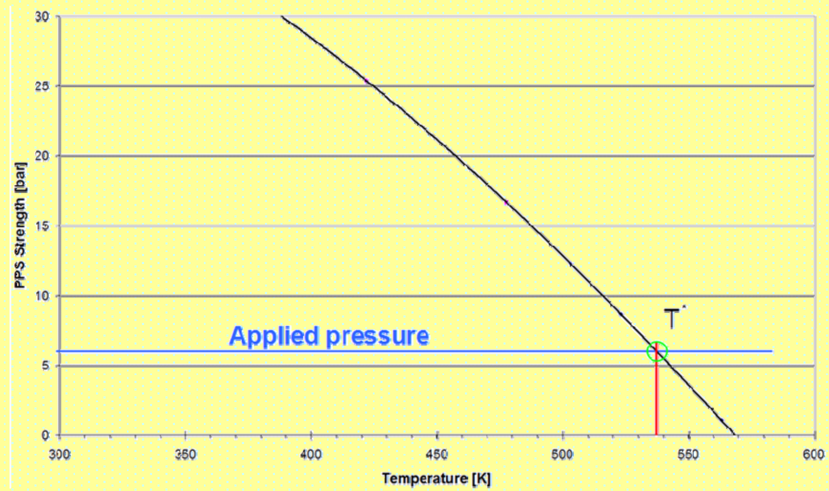
Simulated process	*Power density level*	*Pressure process*	*Current [A]*	*Voltage [V]*	*Time [s]*	*Energy [kJ]*
RW1	5 W/cm^2	6 bar	15.29	8.07	140	1.73
RW2	6 W/cm^2	6 bar	17.17	8.61	100	1.48
RW3	8 W/cm^2	6 bar	19.00	10.20	80	1.55

The heating zone subdomain change during the RW process



T* = PPS resin parameters

T* temperature intersection between the resin strength trend and the applied pressure



TPC RESISTANCE WELDING PROCESS:

THE TEMPERATURE PARAMETERS

TEMPERATURE PARAMETERS

- **THERMAL MATERIAL PROPERTIES:** *k, C_p, ρ*
- **HEAT TRANSFER COEFFICIENT:** *natural convection coefficient*

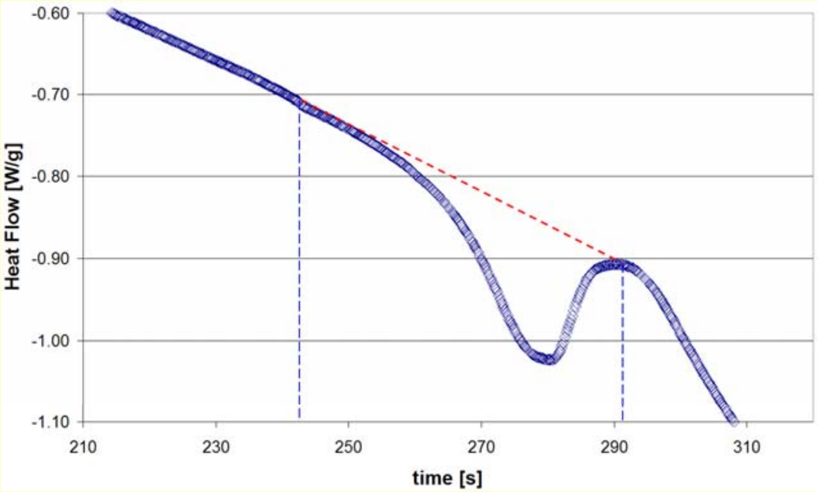
Thermal properties evolution in the heating zone evaluated by mixture phases equation:

$$X(T) = X_R(T) + X_A(T) + X_{MM}(T)$$

$$RA_f = \frac{V_{PPS}}{V_{TOT}} = f(T)$$

The thermoplastic resin need heat to break the polymer link during the heating process.

D.S.C. (Differential Scanning Calorimetric) analysis allowed a heat flow valuation in the heating of PPS resin sample



From experimental measurement was accounted an heat sink in the heating zone

$$Q_{abs} = \dot{Q}\,\rho_{PPS}$$

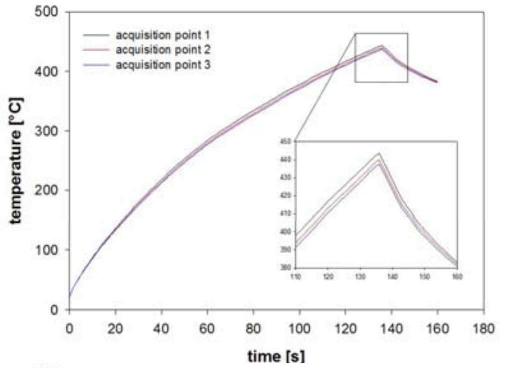
Volumetric heat flow assorbition

Mass heat flow assorbition

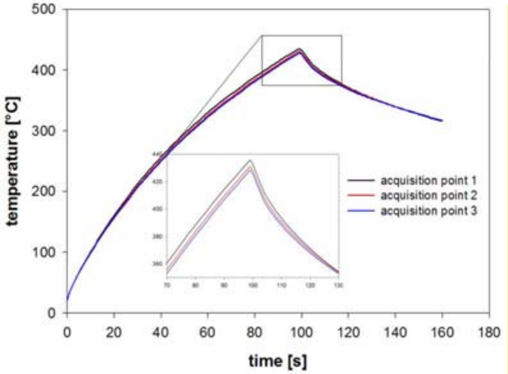
TPC RESISTANCE WELDING PROCESS:
NUMERICAL RESULTS

The temperature – time profiles were reported for three points P1, P2, P3

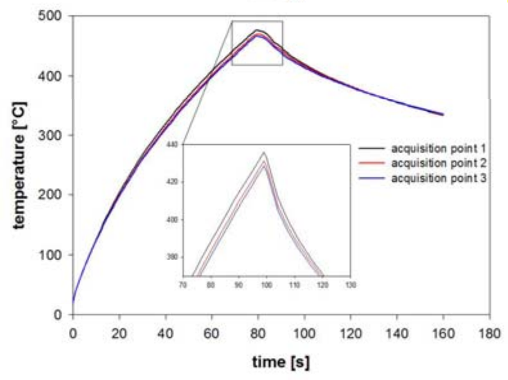
RW1

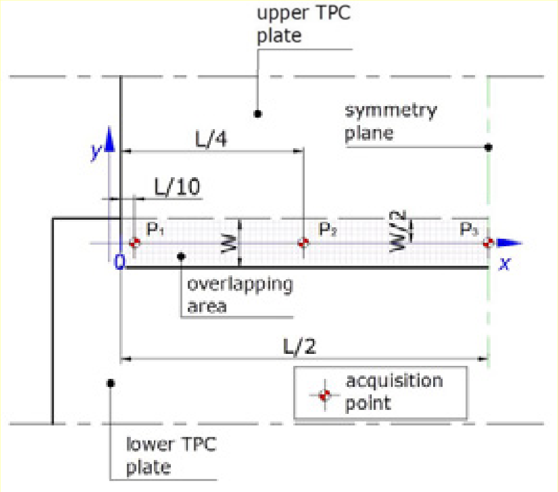


RW2



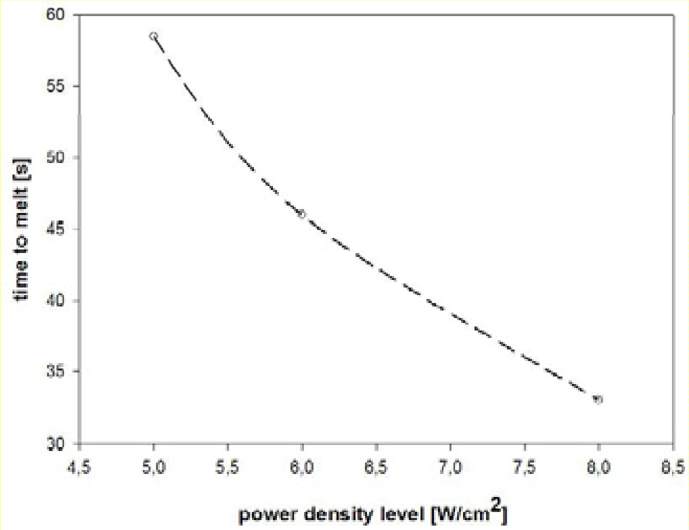
RW3





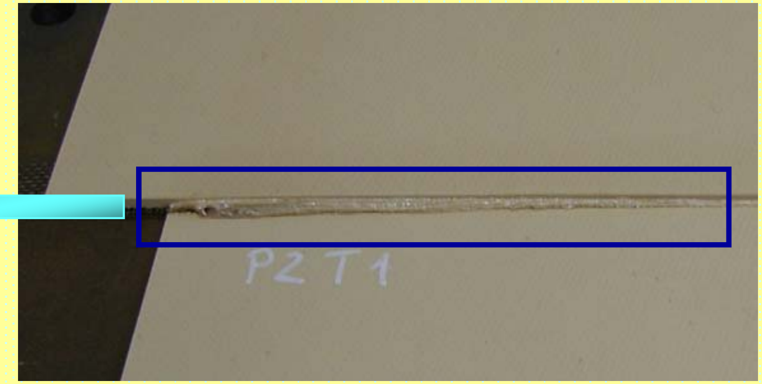
- the leakage phenomenon ⇒ high temperature close to the ends in the overlapping zone
- higher temperature for higher electric power density level tough the process was the shorter one

TPC RESISTANCE WELDING PROCESS: NUMERICAL RESULTS

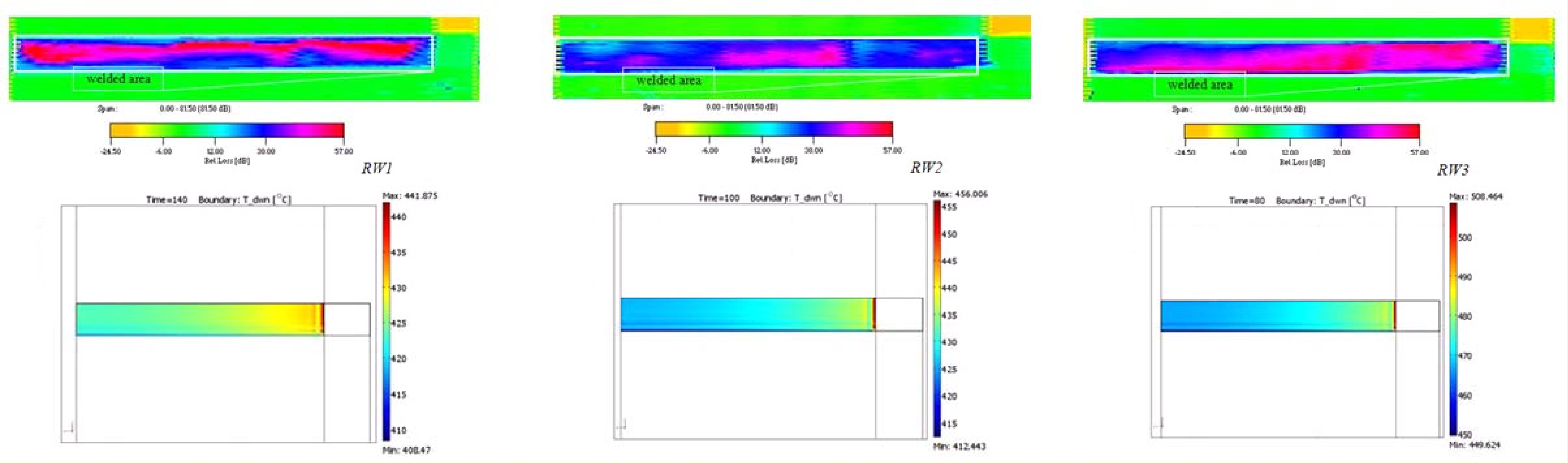


the time to melt showed theoretical "near hyperbolic" dependence from the electric applied power density

long process time together high power density result in a resin squeeze flow



TPC RESISTANCE WELDING PROCESS:
NUMERICAL vs EXPERIMENTAL OBSERVATION



- Squeeze flow rise when resin temperature overcome its higher processing limit (380°C for PPS)
- The experimental results showed higher temperature prediction values

TPC RESISTANCE WELDING PROCESS: CONCLUSIONS

- A numerical ***resistance welding*** process for thermoplastic composite materials was modelled
- The ***heating zone evolution*** was accounted in the model by means a user defined Temperature dependent subdomain equation
- The numerical results allow to compare the influence of the **time process** and ***electric power*** applied level on the temperature distribution and the trend of ***time to melt*** on the applied electric power
- From experimental observation higher temperature prediction values were obtained by the simulations

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THANK YOU VERY MUCH FOR YOUR ATTENTION