The app approach to the heat-seal process

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Heat Seal Experts

- I make no claim to heat seal expertise – I’m only “packaging” the heat seal science from experts around the world:
  - Dr Kazuo Hishinuma, author of the definitive work:
  - Prof Duncan Darby, Clemson University who runs excellent heat sealing courses
  - Sascha Bach, Technical University Dresden who helped greatly with modelling issues and provision of images for this talk
    - [sascha.bach@tu-dresden.de](mailto:sascha.bach@tu-dresden.de)
  - Kevin Chandler from QualityByChoice who has decades of real world heat sealing within the FMG area and helped with “reality checking”
    - [Qualitybychoice@aol.com](mailto:Qualitybychoice@aol.com)
In this talk

- **Jaws** sealing
- **Induction** sealing
- All about the thermal behaviour. *Not* a practical guide to machine design, temperature control, operating procedures, peel strength measurement...
  - See Dr Hishinuma’s book or go to a Prof Darby training class!
- The apps are open to revision, improvements, bells and whistles
  - Your feedback will shape any future developments
  - I enjoy extending/improving app models
Jaws Sealing

- Heated top jaw
- Film stack
- (Optionally) heated lower jaw
- Enough
  - Time ...
  - Temperature ...
  - (Pressure) ...
  - ... to produce a good seal

Sascha Bach, TUD
What do we want to know?

- Effect of jaw temperatures?
- Effect of time?
- Effect of thickness?
- Do we add some PTFE non-stick layers?

- Will we under-seal?
- Will we over-seal?
Pressure

- Irrelevant above a minimal pressure to ensure good contact between the heat seal layers
- A slight excess pressure can create an edge bead
  - Good for protecting the seal from initial cracks
  - Bad for the same reason!
  - It depends if you want permanent or peelable seal
How do we calculate?

- Take any small slice of the stack of polymers for a small time step.
- The heat flowing into it in a short time-step depends on:
  - Temperature difference between it and the hotter slice.
  - Thermal conductivity of the slices.
- The heat flowing out of it in the same time-step depends on:
  - Temperature difference between it and the cooler slice.
  - Thermal conductivity of the slices.
- Do the arithmetic to find the net heat flow into or out of each slice.
- The heat can raise the temperature and, at the MPt, melt the polymer.
  - The heat capacity says how much heat is needed to raise the temperature of a given mass of polymer by 1°.
- So we know the temperature change in each slice for that time step.
- Repeat for the next time step.
Heat capacity

- Closer to the melting points (plural!)
  - It requires more heat to raise the temp.

- The whole calculation is just arithmetic
  - Provided you have the right material props.

- The app has properties for
  - PTFE, PET, PE, PP
  - So you don’t have to worry about any of this!

Sascha Bach, TUD
Heat flow from jaws to polymer

- Normally jaws are Al for high heat conductivity
  - So the set temperature is uniform
  - For maximum transfer of heat to the polymer
- Steel is much tougher but far less efficient at transferring heat
  - A “Steel” option might be possible for the app, but today it is Al-only
- Theoretical transfer of heat from Al to polymer from basic model gives results that are faster than experimentally observed
  - Dr Hishinuma’s MTMS (Measuring Temperature at Melt Surface) places a thermocouple at the melt interface to get real data. Highly recommended!
- Explained by Thermal Contact Resistance (included in the app)
  - In principle dirt and roughness can increase TCR and reduce sealing speed
Sealing

- If the surfaces just about melt together then you get an “interfacial” seal with a relatively low peel strength – but very dependent on exact conditions.

- If they fully melt then the polymer chains become “entangled” and you get super-high adhesion. Once entangled it’s full strength so extra time gives no extra adhesion – and maybe a fall-off from thermal degradation.

- See [www.stevenabbott.co.uk/PracticalAdhesion](http://www.stevenabbott.co.uk/PracticalAdhesion) for an explanation.
To the app
Cooling

- While hot the seal is vulnerable to physical damage
- So cooling is important
- The app estimates convective cooling that differs depending on whether the package is horizontally or vertically aligned (this changes the airflow)
- It is very slow compared to the heating
- Forced air (not in the app) is needed to cool rapidly.
To the app
Induction

- Internal heating source
- Current flow induced in Al layer
- Thin layer, high powers, rapid heating
- Rapidly melt the heat seal layer
  - And the optional wax above
- The cap & container are massive heat sinks
  - Big effect on the whole heating process
  - And also gives rapid cooling
    - Both cap and container are modelled as 500μm thick but only 12μm of each is shown in the app
Power is meaningless – but important

- The kW in your unit are potentially meaningless
  - The effect depends on head design, frequency, distance, which parts of the Al absorb the energy etc. etc.
- But for a given machine the *relative* power is important
  - The reason is the heat sink effect of the container
  - If you heat slowly (lower power) then a large % of the heat is sucked into the container so the seal temperature is low
  - If you heat quickly (higher power) then a small % of the heat has time to flow into the container so the seal is good
- This power/speed/temperature trade-off is the key mystery
  - Super important for sealing to glass instead of plastic
To the app
Polymer choice

- Low branching polymer gives sharp response
  - All or nothing
  - OK if just above threshold
  - Catastrophe otherwise

- Highly branched polymer gives broad response
  - More forgiving
  - But maybe harder to get very high peel as they are less “entangled”
Team working

- The ideas are simple
- The calculations are done for you in the apps
- The whole team can play “what ifs” and everyone can see the outcomes

- Good luck – and don’t forget to give me bug reports, feature requests etc.
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- Now to your questions...