DR.FRITSCH

Reason and use of the transformer-tappings for FAST/SPS-sintering in conjunction with the right mould design

Gerhard Weber, president of Dr. Fritsch

Summary

With the FAST/SPS heating concept, the workpiece and the mould are heated directly by the resistance heating principle. The generated heat is directly dependent on the energy transformed in the electric circuit. The secondary voltage of the transformer can be adjusted by choosing the right tapping on the primary side, while the mould design has a direct impact on the resistance in the circuit. If these 2 factors are optimised, process time and process energy can be saved.

The sintering presses of the company Dr. Fritsch are normally offering several tappings on the heating transformer. But these tappings are not always used in the field.

The FAST/SPS-principle works fundamentally different to the usual oven sintering. We cannot just push our mould into the press and heat up indirectly by convection. Rather, the mould design is an integral part of the concept, since this mould is directly heated. No wonder, these machines are also called resistance-sinter-presses.

The tappings are used to adapt the secondary voltage to the mould. The resistance of the mould determines how much energy the mould can take up at a given voltage.

Additionally, the power intake is regulated via a power controller, e.g. a thyristor controller. This controller takes care that the maximum power of the machine is not exceeded, by regulating the power via phase modulation of current and voltage.

Here some general comments:

The resistance of a sintering mould is depending on several factors:

- The specific resistance of the mould material (very often, graphite is used; different graphite specifications have a different specific resistance). If the specific resistance of the mould material is higher, the overall resistance of the mould is higher. A metal mould has typically a much lower resistance than a graphite mould.

FIGURE 1 – Transformer tappings on a DSP 520.

- The surface area of the mould – If the surface gets larger, the resistance gets lower, more current can flow "parallel" through the mould.
- When the height of the mould gets bigger, the resistance gets bigger. If the height doubles, it's like placing 2 moulds on top of each other – we double the resistance.
- The sintering pressure has a certain impact. When the pressure is increased, often the contact

resistance of the mould, or better the contact resistance between electrode and mould, is reduced.

- The specific resistance of the graphite is changing according to the temperature. With growing temperature, the specific resistance is falling until app. 900°C, then the resistance starts rising again.

A first indication is given by Ohm's law:

$$U = R * I$$

With U = Voltage; R = Resistance; I = Current

Furthermore, we have:

$$P = U * I$$

With P = Power

Case 1 – Optimum mould layout.

With an ideal mould layout and a machine working under full load, the machine (e.g. a DSP615) delivers the full capacity to the mould and the mould takes up the full power.

P would be 173kW, U = 4V and I = 43kA. (Simplified, losses neglected).

However, this would practically happen only for a short time, as the mould would heat up and – as we learned above – change its resistance.

Case 2 – Too high resistance of the mould.

If we put 2 moulds on top of each other, each mould gets only 2V. We have practically doubled the overall resistance. The power controller opens up fully, but the real current is now much lower. We can read on the display, that we have the full voltage, but the power is much less than 100%. This is clear, since P = U * I and I (our current) is now low. A typical sign for a mismatch of the mould is, when the mould takes up only little power but this power increases with increasing mould temperature. Also typical is an increase in power uptake by switching from lower pre-pressure to main pressure.

A remedy is to „tapp up" the voltage. We can go from 4V to e.g. 5V. With the same current, we now have a higher voltage und thus a higher power (with P = U * I).

A typical example for this case is the sintering of rings (low active sintering area) or sintering with double frame, the sintering of non-conductive material or with the excessive use of non-conductive release agent (e.g. Boron-Nitride).

Case 3 – Too low resistance of the mould.

With the opposite case (too low resistance of the mould), we get the following picture:

The mould cannot take up the full power (the display of the machine shows e.g. 60% power) and the machine limits the power. The machine works practically in a short-circuit, the power controller limits the current to prevent a machine overload. How can we now identify such a case?

- Initially, the mould heats up well, but the machine runs out of power with rising temperatures.
- On the display of the power controller (inside of the machine), a red dot is shown.
- The primary voltage on the display of the machine goes down, although we can see that the full current is available.
- When we increase the pressure on the mould, the heating rate is further reduced.

When does this happen?

- Cheap graphite (often from overseas). Simplified: The specific resistance of the graphite is adjusted by the internal porosity. It is difficult to obtain a high fracture strength despite high porosity is difficult. To guarantee the necessary fracture strength, the porosity of cheap graphite is reduced and thus the conductivity of such graphite is increased (the specific resistance goes down).
- Too high active sintering surface – we just demand more of the machine than it can deliver.

What can we do now?

- We check if the transformer is tapped on the lowest step – we want to work with the lowest possible secondary voltage.
- We increase the resistance of the mould, by …
    - …reducing the mould size (less segments means less surface).

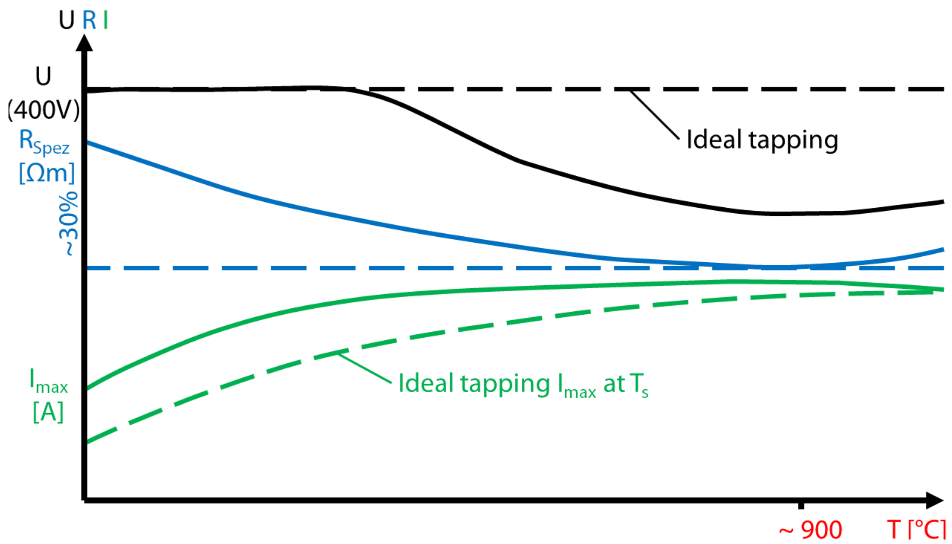

FIGURE 2 – Correlation between U, R and I in relationship with the temperature. The graph of the ideal tapping is shown as a dashed line.

  - … increasing the height of the mould (e.g. putting 2 moulds on top of each other).
  - … changing the mould material (more specific resistance).
  - … increasing the overall resistance of the mould by adding CFC plates above and below the mould.

Furthermore, we can use a few indirect improvements that are not changing the resistance but are giving a bit more leeway to the machine:

- Better insulation of the mould. We can reduce the energy radiation and thus more energy remains to heat up our mould. We can achieve this by more insulation material in our clamping frame or by wrapping our round mould with graphite felt.
- We try to realize as little contact area between the passive mould parts and the electrodes as possible. For grinding wheel moulds or wire bead moulds, we put some insulating paper between electrodes and outer mould ring, respectively electrodes and side plates.
- We optimise our mould design to get a better ratio between active sintering surface and the total mass of the mould. Especially with drilling rings or grinding wheel moulds with thin rims, the mould has often a high mass, although the active (current carrying) sintering surface is quite low. That happens often, if a mould is used in a sinter press, although it has been developed originally for oven sintering.
- We check if our graphite electrodes are heavily worn and are ground too thin over time. Thin electrodes transfer more heat into the water cooled brass plates and we are losing too much energy into the cooling water, while at the same time the overall resistance is lower than with new and thicker electrodes.

The situation is schematically shown in Figure 2. The dashed green line shows the current graph with ideal tapping. The solid green line shows a situation, where the power controller runs into the limiter. Here we can see (black line), how the voltage is cut by means of phase modulation to limit the current. In principle, the ideal mould set-up should be determined by practical tests. An experienced machine operator knows approximately, what mould design will make the machine work best. But even then, sometimes we can see a surprise, e.g. if a new graphite supplier is found. Especially with very big moulds (e.g. for brake pads), even the differences between graphite batches of the same specification can have a clear impact.

Dr. Fritsch Sondermaschinen GmbH

Dieselstraße 8
70736 Fellbach / Germany

Phone: +49-711-51832-0
Telefax: +49-711-51832-10

Homepage: www.dr-fritsch.de
E-Mail: info@dr-fritsch.de