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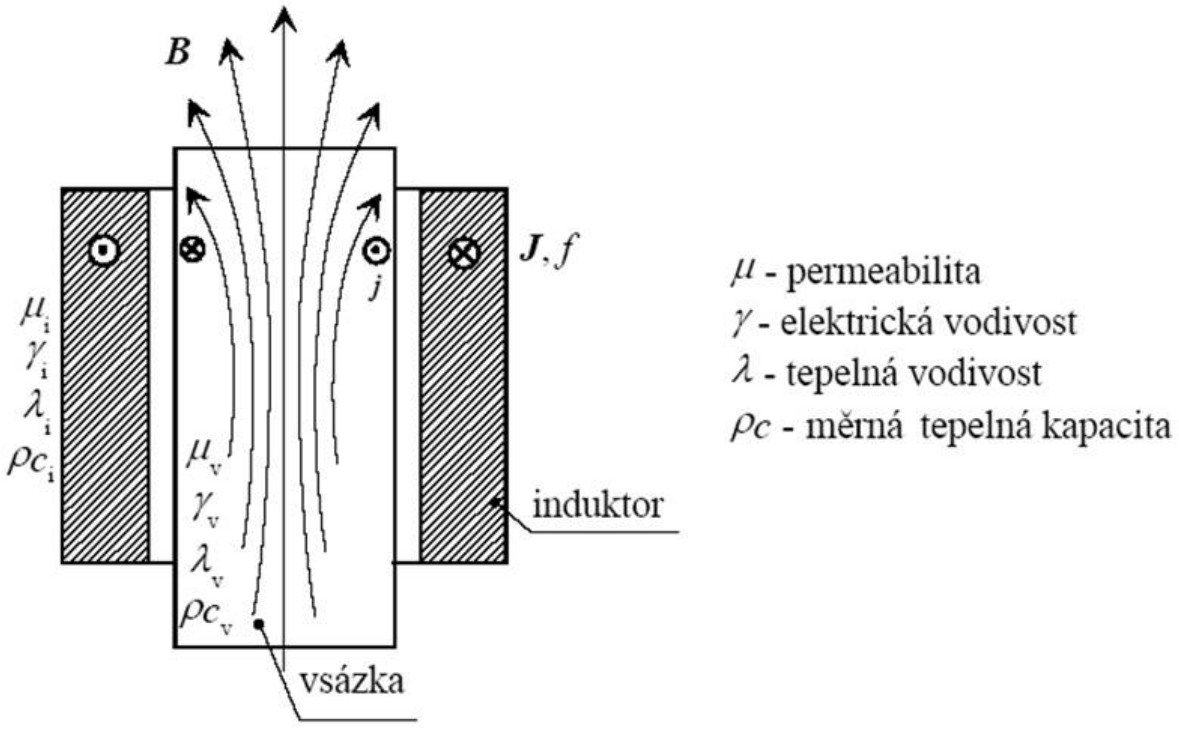
Determining the temperature field distribution in an electrically conductive plate during induction heating

Home

The use of induction heating enables a very precise and very gentle way of heating the heated insert compared to e.g. direct and indirect resistance heating or flame heating. The greatest advantage of induction heating is that heat is generated directly in the insert as a result of Joule losses caused by the induced eddy currents generated by the coil's variable electromagnetic field. If we know the distribution of the induced currents, we can determine the distribution of the Joule losses, which will be proportional to the heat generated. The heat induced by the losses will be proportional to their magnitude and to the time they are in the cell. The greatest heat development will be at the points with the greatest losses, from which it will propagate through the heat conduction to the entire embedment.

Theories

Induction heating can only be used with electrically conductive materials. Eddy currents are induced in an object made of conductive material that is placed in an alternating magnetic field, which heats the object. In a simplified way, induction heating can be compared to a transformer where the output winding is a load (secondary winding shorted). Energy is transferred to the charge by an alternating electromagnetic magnetic field and heat is then generated directly in the charge.
The bet is the warmest object in the whole system - everything else can be cold. The generation of heat directly in the charge, with the charge not mechanically bound to anything, is one of the greatest advantages of induction heating. The principle of induction heating is shown schematically in the induction heating figure below. The charge, which must be sufficiently electrically conductive, is inserted into an inductor flowing with an alternating current of density **J** and frequency f. This induces a magnetic field **B** passing through the insert, in which eddy currents of density **j** are subsequently induced.
The depth of heating of the embedding can be well controlled by frequency - as the frequency of the excitation current increases, losses and therefore heat are generated in thinner and thinner surface layers.



Schematic representation of induction heating

Induction heating is usually a very energy-intensive process and it is necessary to optimise the entire system so that its efficiency is as high as possible for the specified process requirements. In induction heating, the object to be heated is in the position of a shorted coil and the current flow in the coil leads to heating of the material. Theoretically, all electrically conductive substances can be heated by an alternating electromagnetic field; in practice, it is mainly metals that are heated by induction.

The principle of the induction cooker

The hob (cooking zone) of the cooker contains a coil which is powered by a large alternating electric current. The coil is wound from high frequency rope (twisted mutually insulated copper wires), it is a very good electrical conductor and at the same time the surface effect of the whole rope is limited. A magnetic field is created in the coil, which generates heat in two different ways:

By applying a magnetic field to the electrically conductive bottom of the vessel, eddy currents are induced in the vessel, which are converted to heat by the electrical resistance of the vessel. A small part of the heat is also generated by hysteretic losses in the ferromagnetic material of the vessel during its magnetisation. From the heated ferromagnetic layer at the bottom of the vessel, the entire bottom and the entire cooking vessel are gradually heated and, consequently, the heated contents of the vessel.

Measurement objectives

1. Determine how much power the induction cooker operates at the specified power levels.
2. Approximately determine the energy required to heat the steel plate from the initial to the desired temperature.
3. Record temperature at defined points with the Omega RD880 digital coordinate recorder
4. Monitor the temperature of the entire board with the Flir T335 thermal imaging camera.
5. At a specified distance from the cooker, measure the magnitude of the scattered electromagnetic field induction using the ELT 400 probe.
6. Using an oscilloscope and oscilloscope clamps, determine the frequency of the current through the inductor

Measurement procedure:

Using an induction cooker connected via an electric meter, heat the steel plate according to the 3 specified heating stages. There are 6 thermocouples attached to the plate, which are fed to a digital coordinate recorder. Throughout the heating process, you will use the digital coordinate recorder and a thermal imaging camera to monitor the heating of the steel plate to a temperature of 300
°. Every 30 s of heating, you save a snapshot of the temperature field of the heated steel plate using a thermal imaging camera

You will switch the induction cooker gradually according to the power levels you set. The time of each heating sequence will be tracked, and you can then use this to determine the power the induction cooker has been operating at during the heating sequences by knowing the energy drawn from the mains.

At a specified distance from the cooker, you will measure the magnitude of the scattered electromagnetic field induction using the ELT 400 probe.

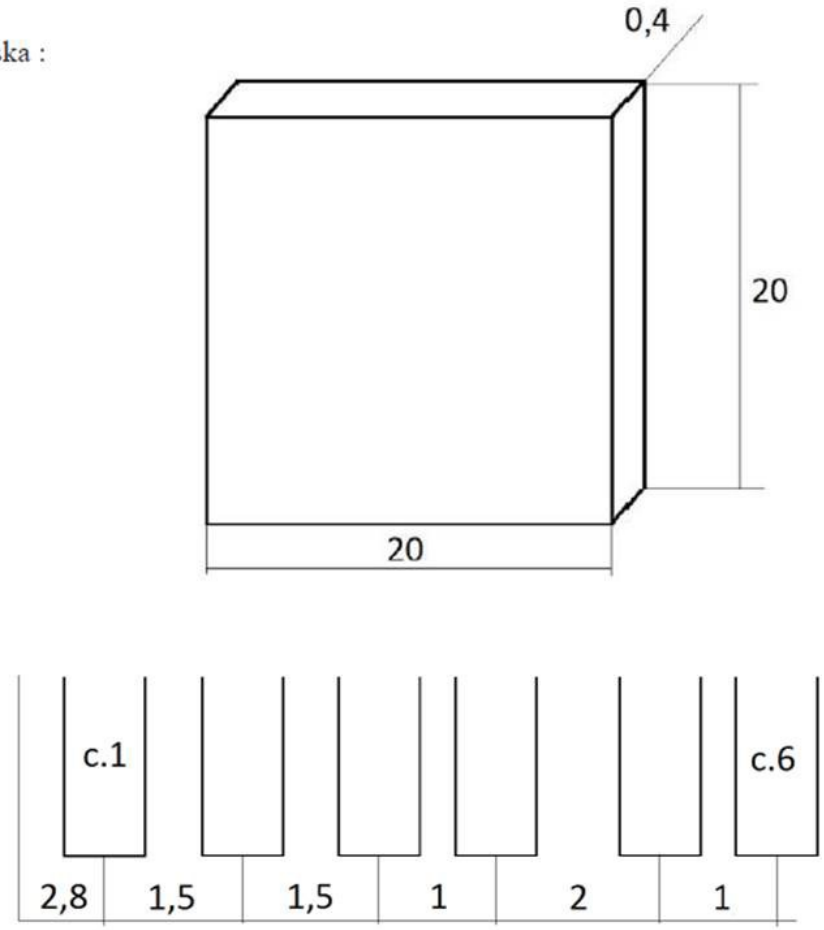
For each measurement, you attach an oscilloscope clamp to the inductor of the cooker and connect it to the oscilloscope so that you can determine the frequency of the current passing through the inductor conductor.

Calculations

Dimensions of the heated steel plate with the relevant material parameters and an example of the possible connection of thermocouples for contact temperature measurement.

měřená ocelová deska :

uhlíková ocel
$\gamma = 2.10^6$ S.m
$\mu_r = 100$
$\lambda = 25$ W/mK
c = 370 J/KgK
$\rho = 7700$ kg/m^3



Obr. 1 Umístění termočlánků na ocelové desce v [cm]

Calculate the mass of the plate:

$$m = \rho V[kg]$$

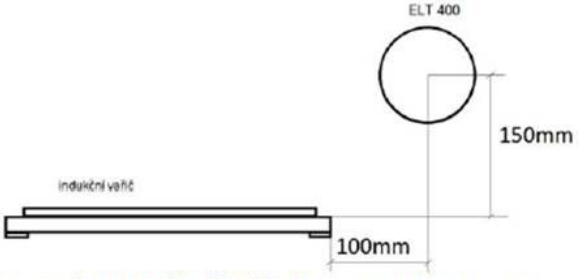
Determine the energy required to heat the steel plate from its initial state to the desired temperature

$$Q = mc\Delta\vartheta[J]$$

The following figure shows an example of a table for recording the required quantities with an example of a possible location of the probe for measuring the electromagnetic field. Adjust according to your actual measurement.

Příkon [kW]	Frekvence [kHz]	Mg.indukce [μT]
1,9	23	13
1,3	26,5	9,5
0,9	28	7

tab. 1 hodnoty naměřené při daných příkonech indukčního vařiče



obr. 2 Umístění ELT400 při měření rozptylového mg. pole

Determination of appliance power input

At 1st power level						
Measured point	**A**	**B**	**C**	**D**	**E**	**F**
Temperature of measured points [°C] when the cooker is switched off						
Meter status		the beginning:		kWh		
		The end:		kWh		

Indicate the electrical energy consumed [J] Indicate

the heating time [s]

Determine the power input of the induction cooker [W]

Attach images taken by the thermal imaging camera at 30 s intervals

Plot the measurement data using a digital coordinate recorder. Follow a similar

procedure for the 2nd and 3rd power levels of the induction cooker.

Indicate the instruments used:

State the conclusions from the process and result of the measurement:

Instructions for using the measuring devices can be found in the courseware of the course.

At the same time, you will also find a video-training of a specialized worker on how to use the thermal imaging camera on:

http://kryton.zcu.cz/public/GALERIE%20-%20TRANSFER/KA2_advanced/IRCAM_Analyzer_siti_20110913.mp4