Induction Heating Principle

The principle of induction heating by RF electric current is shown in Fig.-1, there an electric conductor such as iron or steel placed in the inductor is heated rapidly by induced eddy current caused by electromagnetic induction, and hysteretic heat loss, which is generated by vibration and friction of each molecule in magnetic material under AC magnetic flux.

As RF frequency, which is higher than that of commercial electric power, is used for induction heating, induced current flows only in the limited area near surface of heated material because of skin effect and proximity effect, and heat loss occurs only there by eddy current and hysteretic loss. The skin effect is the phenomenon, which RF electric current flows only in the limited area near surface of conductive material, and proximity effect is the phenomenon, which the primary current in the inductor and the secondary current in the conductive material pull each other because the direction of current is opposite each other, and flows in the limited area near surface where distance is nearest each other.

Fig.-2 shows the relation between frequency and depth of RF electric current flow for steel material heated by induction at 1,000 degree. The depth depends upon the frequency and as the frequency is higher, the depth becomes smaller as shown in the curves in Fig.-2.

The penetration depth is defined as the point where RF electric current decreases to about 37% (1/e =1/2.718=0.368; e is the base of natural logarithm) compared with the current at the surface and normally expressed as S . In Fig.-2, the penetration depth is shown as the points, which are the cross points of line A with the current penetration curves. The penetration depth S is calculated as follows.

S =5.03 x/^rf (cm) S =
penetration depth (cm)
j = specific
permeability
(magnetic material: j>1, non-magnetic material:
j = 1) f = frequency (Hz) p = specific resistance
(jQ' cm)

This formula shows that as the frequency is higher, S will be smaller and the heating will be concentrated at the surface in case the materials are same. However in actual heating, the heated depth tends to become bigger because of heat conduction in the heated material. (Refer to Setting of Hardening Condition item (3) Choice of frequency)

Fig.-1: Principle of induction heating

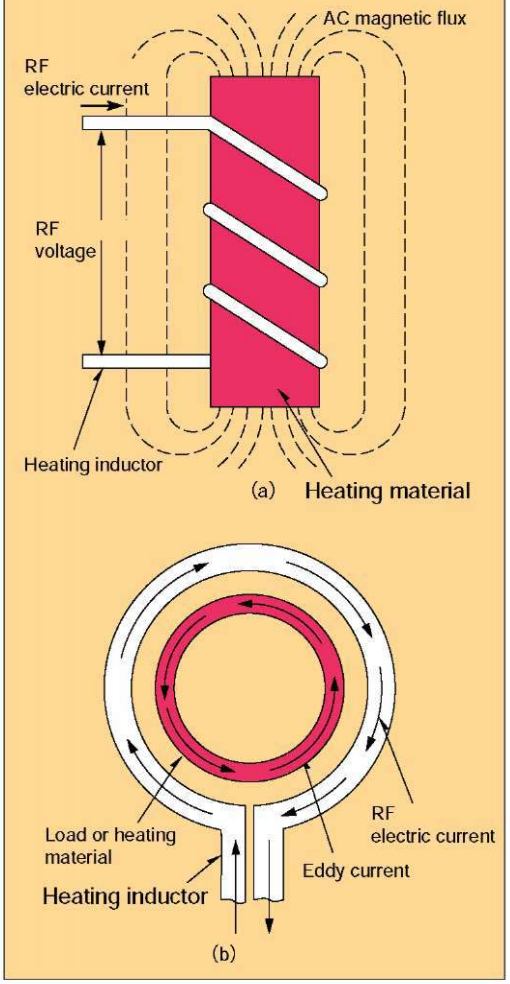

Fig.-2: Electric current distribution and penetration depth δ (cm) for steel material (at 1,000 degree)