SYNOPSIS

It is necessary to characterize microstructures by non-destructive evaluation (NDE) techniques for two purposes, namely (a) for assessment and extension of component lives, and (b) for assessment of heat treated microstructures in a component before putting it in service. It is desirable that the NDE parameters should be sensitive to the microstructural changes in such a manner that it would be possible to understand the type of microstructures present in a component without resorting to the conventional microscopy techniques. This requires an understanding of the relationship of the microstructural features with the NDE parameters. Towards this end, three steels of commercial importance, namely 9Cr-1Mo ferritic steel, 2.25Cr-1Mo ferritic steel, and 17-4PH precipitation hardenable stainless steel have been chosen in this investigation. Different types of microstructural changes take place in these steels. The non-destructive techniques chosen are based on magnetic and ultrasonic behaviour. These two classes of techniques are the most promising NDE techniques for microstructural characterizations. The NDE parameters have been correlated with the microstructural features by carrying out microstructural analyses using conventional techniques such as optical microscopy, scanning electron microscopy, and transmission electron microscopy.

The NDE parameters used are: Coercivity, retentivity, peak height peak position, and shape of rms voltage plot of magnetic Barkhausen noise, peak height of rms voltage plot of acoustic Barkhausen noise, ultrasonic velocity, and elastic and shear modulii. For the magnetic parameters, the necessary equipments have been built specially for this investigation. Additional parameters used are: Full Width at Half Maximum (FWHM) of XRD peak of the \{211\} planes.

The heat treatments were chosen such that the microstructures would represent some of those expected in practice. The initial microstructures in the steels were martensite. Ageing of the martensite microstructures was carried out at different temperatures for different durations of time. For 9Cr-1Mo steel, the martensite microstructures were also studied by using different
austenitizing temperatures and cooling rates.

Important results are as follows:

9Cr-1Mo steel: (a) Incipient occurrence of delta ferrite could be detected from coercivity, retentivity and MBN peak height; ultrasonic parameters were not useful for the same; (b) When single phase martensite is present, Hall-Petch relationship w.r.t. coercivity and hardness was observed. Such a relationship is absent when pro-eutectoid ferrite is present apart from martensite indicating the influence of the ferrite not in terms of its effect on grain size but through its presence per se; (c) In the furnace cooled specimens, increased coercivity, higher hardness of the martensite, lower levels of MBN peak heights, consistently higher values of FWHM of the XRD peaks of the \{211\} planes indicated the occurrence of carbon partitioning from ferrite to the austenite when the steel was cooled. An effect of the possible carbon partitioning to the austenite was an increase of the hardness values of the martensite in the furnace cooled specimens as compared to that of martensite in the water quenched specimens; (d) MBN peak height, retentivity, velocity and modulii values were found to be sensitive parameters to differentiate martensite microstructures obtained by different cooling rates; (e) Stress relief annealing significantly affected the magnetic and the ultrasonic parameters; the presence of the M$_{23}$C$_6$ carbides or the M$_X$ phase did not affect the parameters; (f) From an understanding of the orientation of the M$_X$ phase, shape of the rms voltage plots of MBN, and the variation of ABN peak heights, it was possible to assess the time ranges within which the M$_X$ phase would be removed from the microstructures when a stress relief annealed specimens having M$_{23}$C$_6$ carbide and M$_X$ phase are aged; (g) Ultrasonic velocity and modulus were found to be insensitive to the microstructural changes occurring due to ageing and in martensite obtained by different conditions of cooling rates.

A major gain from the work on 9Cr-1Mo steel is the observation that, under certain circumstances, the width of the rms voltage plot coupled with the peak heights of ABN gives important clues on the microstructure than the more conventional MBN parameter of peak height.
2.25Cr-1Mo steel: A combination of parameters such as MBN rms voltage peak heights and their positions, ABN rms voltage peak height, coercivity, FWHM of the XRD peak of the \{211\} planes was found to be a good pointer to the sequence of carbide dissolutions and precipitations that take place when the oil quenched steel was aged at higher temperatures. The carbide stability diagram of Baker and Nutting (JISI, July 1959) was used as the criterion. A major gain from the work on 2.25Cr-1Mo steel has been the observation of multiple peaks in MBN rms voltage plots as manifestations of different source mechanisms due to the presence of various carbides in the microstructure.

17-4PH steel: (a) The interlath copper rich spherical precipitates occurring as a result of ageing did not affect the magnetic parameters such as coercivity and MBN peak height. However, the intralath precipitates had a great influence on them; (b) Retentivity was found to be a sensitive parameter to identify the region of hardness peak; (c) Apart from retentivity, MBN peak height was also found to be useful to identify the region of peak hardness; however, coercivity was not found to be a good parameter for the same; (d) Ultrasonic velocity and modulus increased as soon as the ageing started from the water quenched state due to the relieving of internal stresses. The intralath and interlath precipitates did not show significant effect on the ultrasonic parameters.

A major gain from the work on 17-4PH steel has been both retentivity and MBN peak heights are useful parameters for monitoring the occurrence of hardening peaks; therefore, these two parameters can be used as "proxies" for hardness in this case. Coercivity was found to be a good parameter in the post hardness peak region.

This investigation has shown that, if the microstructural changes occurring in a steel are understood, then there is a possibility of correlating them with the variations in the magnetic and the ultrasonic parameters. As compared to the magnetic parameters, the variations in the ultrasonic parameters were found to be less sensitive to the microstructural changes considered. Often, the use of a single parameter was found to be insufficient. It was necessary to use more than one parameters to have a better understanding of the microstructural changes taking place.