EXPERIMENTAL KNOWLEDGE OF WET STEAM TURBINES

by A. Smith

Influence of moisture on blading efficiency

In conventional fossil fired power stations the gain in efficiency obtained from the adoption of higher superheat and reheat temperatures is predominantly thermodynamic, improvements from the reduction in moisture content being small, since this is restricted to the last two or three stages of the low pressure (L.P.) turbine which represents only a small proportion of the overall heat drop. Economic and technical considerations in water moderated reactor systems, however has favoured a reduction in initial steam temperatures so that the expansion is now predominantly wet. Attention has consequently been refocussed on the additional losses suffered by blading when operating in wet steam.

The first published reference to wet steam losses was made by Karl Baumann(1) who proposed that a good approximation to the wet isentropic efficiency of blading could be obtained by multiplying the dry efficiency by the mean equilibrium dryness fraction, the isentropic heat drop being based on the value read from the Mollier diagram. It is worthy of note, however, Prof. A. Stodola did not agree with his pupil and in his treatise(2) specifically mentioned that no additional wetness loss was evident from his experiments on an eight stage reaction turbine.

Today few would support this finding, but Prof. Stodola's article does serve to clarify that the steam tables are based on unit mass of mixture and that the enthalpies quoted below the saturation line are debited with the reduction in total heat caused by the presence of water. The Baumann factor therefore accounts for a supplementary wetness loss in addition to that resulting from the reduction in isentropic heat release caused by the presence of water.

In 1931 Soderberg(3) made an important contribution to wetness loss studies by subdividing the sources of loss into three effective areas before quantifying them. Initially he calculated the energy required from the steam to accelerate the droplets from rest at the blade trailing edges up to a given proportion of the mean steam discharge velocity both on the stationary and moving rows. He then considered the individual contributions of the vapour and water phases to the change in absolute tangential momentum across the moving blade rows from which a braking loss was deduced and finally he estimated the losses associated with centrifuging the water deposited on the moving blade surfaces to the cylinder wall.

The result of these combined wetness losses on 50% reaction blading, set at 0.4 opening coefficient (o/p), indicate that the loss factor (α) defined by $\eta_W = \eta_D\ (1 - \alpha Y_m)$, decreases with the ratio of blade speed to steam efflux velocity (U/C) (Fig. 1). The loss factor is also sensitive to the ratio of droplet to vapour velocity at entry to the blade rows, falling as this ratio approaches unity, a condition that might apply in a high pressure (HP) turbine where reatomization of water would be improved by the high steam density which would result in a reduction in water braking loss.

Effectively Soderberg had restricted his analysis to wetness losses associated with the second and subsequent generations of droplets, avoiding the losses associated with the very much smaller first generation droplets formed in a reversion process. Consequently, condensation shock losses, which, if sufficiently strong, would cause additional boundary layer separation losses, were omitted as well as the subsequent drag losses associated with the first generation of droplets. Analytical difficulties with these, as well as end effects associated with blade tip leakage and stirring losses close to the turbine cylinder walls, have consequently tended to favour an experimental approach.

Because of the high heat drop necessary to produce wet steam of representative quality from a dry and saturated initial steam condition, most turbine wet loss experiments have been made with water injection either into steam or air[4]. The results have consequently been more applicable to the later stages in a wet expansion where the majority of the water droplets present are likely to be of the coarse second generation variety. An example of this technique obtained from a seven