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Grundlagen einer Theorie der Naßdampfturbine

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Summary

A satisfactory analysis of the phenomena in low-pressure steam turbines caused by the presence of wetness and by the non-equilibrium behaviour of wet steam is only possible if the arbitrary assumptions on droplet size, a common characteristic of most earlier publications on this topic, are replaced by more reliable informations. In the present work the attempt is made to derive an initial average droplet size by analysing the nucleation process, and to use this for a theoretical analysis of the processes the moisture is involved in while passing through the stages of the turbine.

Concerning the unset of moisture formation, there is only an utterly insignificant condensation on the surface of the blades and the walls after passing the saturation line. As a matter of fact, supersaturation increases rapidly and brings about a spontaneous nucleation of the steam ("Wilson-line"). The exact position of the Wilson-line and particularly the size of the produced "fog" droplets depends strongly on the expansion rate, which prevails in the region where the nucleation takes place. If the nucleation zone is within a blade row where a considerable expansion takes place, the medium fog droplet diameter is of the order of $2\bar{r}_n^{**} = 5.10^{-8}\mathrm{m} = 0{,}05\ \mu$ (see Fig. 2.5.14); if, however, nucleation happens to take place in a region where the pressure is almost constant, relatively large fog droplets ($2\bar{r}_n^{**} \approx 10^{-6}\mathrm{m} = 1\ \mu$) are produced. A fraction of these fog droplets impinges on and is captured by the blades in the following stages (other types of coagulation turn out to be unimportant), thus giving rise to water films or brooklets which flow towards the trailing edge (on stator blades) or towards the blade tip (on rotor blades) and spray off as relatively large, erosive drops. (Drop sizes of the order of $2r_g = 10^{-4}\mathrm{m} = 100\ \mu$.)

Droplet sizes and the distribution of moisture mass among the various droplet classes along the stages of the turbine have been calculated for several representative examples (Chapter 2.9). Depending on the initial fog droplet size and the number of stages the fog has to pass through, the mass of water transferred to the "dangerous" (erosive) forms amounts to 5% to 30% of the total wetness present at the end of the turbine. The rest prevails in form of a finely distributed fog (see y-charts in Figs. 2.9.4 etc.). Also the amount of undercooling necessary to keep condensation going on at the surface of the droplets is largely dependent on the fog droplet size (see ΔT-charts in Figs. 2.9.4 etc.).

The various efficiency losses, resulting from the presence of wetness and from the non-equilibrium states of steam, have been calculated. One finds, rather independently from the kind of turbine, a worsening of the total efficiency of the wet stages by 0,3% referred to 1% medium wetness for extremely small and by 0,7% for extremely large initial fog droplet sizes. Meanwhile, the loss in the individual stages is shown to be far from proportional to the medium wetness of the stage, see Figs. 3.7.1 and 3.7.2.

On the basis of these results several conclusions of practical interest can be drawn, e.g.: A high degree of drainage indicates that the turbine is running under unfavourable conditions (large fog droplets are being produced). Since only the "dangerous" drops can be removed from the steam, no really high degree of drainage can ever be expected. The most promising way to improve the efficiency and to reduce the danger of erosions consists in assuring a fine fog quality, i.e. in keeping the nucleation zone within a region where the pressure is sinking rapidly.