Sold Particle Erosion and Mechanical Damage

The third article in a three-part series describing how to effectively perform steam turbine steam path audits.

Solid particle erosion and mechanical damage degrade the steam path in several ways. They change the surface finish, almost always for the worse. They change stationary and rotating blade flow areas, sometimes increasing and sometimes decreasing them; and they introduce irregularities in the steam path that result in eddy generation with the resulting losses these eddies produce.

In the second of this three part series, we talked about how to determine how much your observed surface finish differs from the best achievable, and what the difference is costing you. For this presentation we will focus on how to measure and evaluate the impact of area change and irregularities in the steam path that result from erosion and foreign object damage.

Figures 1 & 2 are examples of solid particle erosion and Figure 3 shows an example of a significant case of mechanical damage. Clearly these present a performance evaluation challenge.

Figure 1

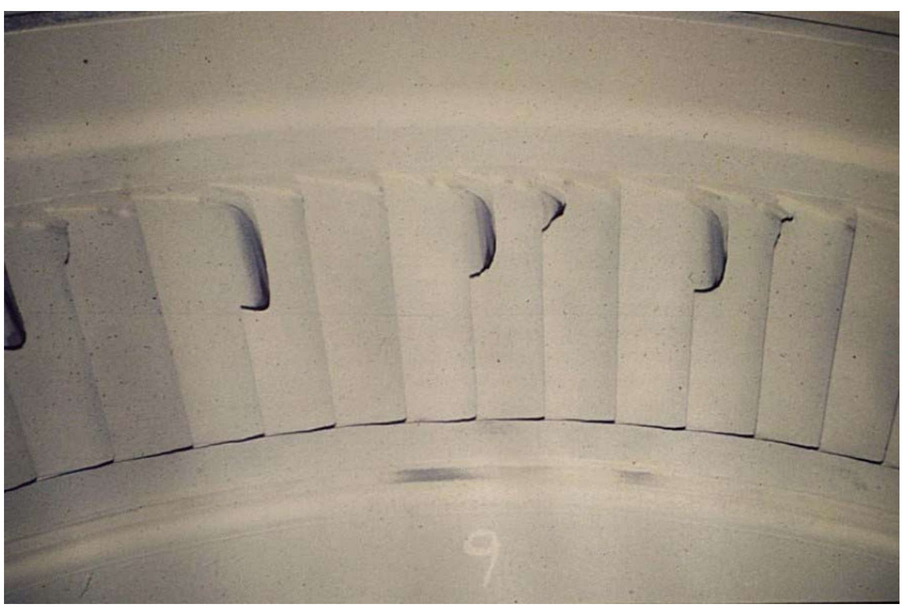

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Figure 2

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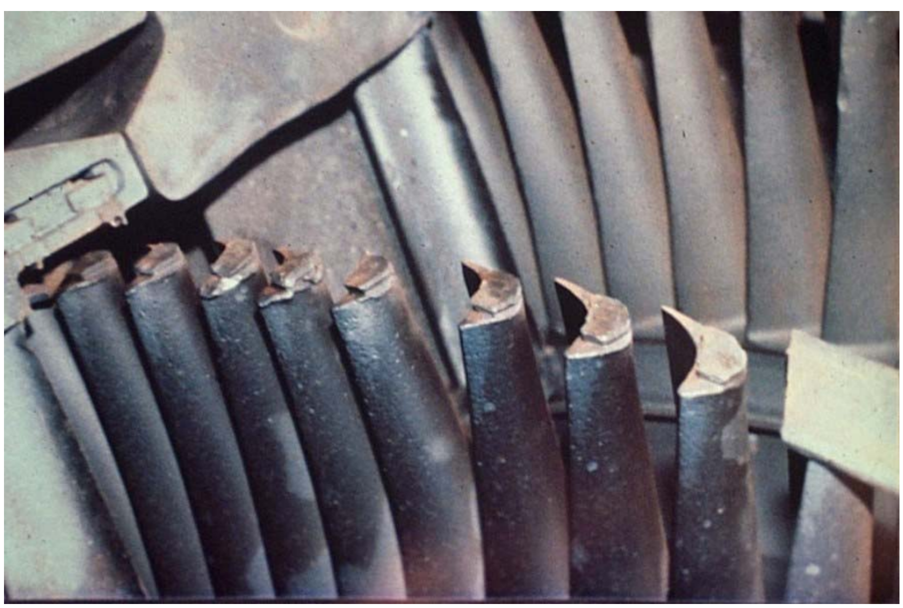
Figure 3



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Solid Particle Erosion

A characteristic of solid particle erosion is that the amount of erosion is different on every blade, as can be observed in Figures 1 and 2. To aid in evaluating this condition, Encotech has developed a categorization procedure. The person conducting the audit will group all of the blades in the stage (stationary are evaluated separately from rotating blades) into four categories: one with the greatest amount of erosion, one with the least amount, and then two in between. The auditor then enters the number of blades in the category.

The next step, for each category, is to select a typical erosion geometry. The Encotech eSTPE program offers the option of a square, rectangular, or triangular profile. A measurement of the mean height, in the radial direction, and the depth of erosion into the blade profile is then recorded. An additional entry, called "tapering" is required at this point. In regions where the trailing edge is still intact, there may, nevertheless, be an erosion of the pressure side of the airfoil which thins the trailing edge and increases the stage flow area. The entry is an estimate between 0% and 100%.

Following entry of the observed data for both the stationary and rotating blading in the stage, the eSTPE computer program makes use of stored data defining the typical increase in flow passage area, as you move upstream from the blade exit; and determines the mean change in the blade row minimum area for both the stationary and rotating blade rows independently. This information, along with a velocity coefficient reduction that is proportional to the amount of erosion, is then used in a velocity diagram type of calculation to determine the impact of the erosion on the stage efficiency.

Having determined the change in stage efficiency it is then possible for the computer program to calculate the change in power output from the stage and the impact on turbine cycle heat rate. These results are then presented in the computer output screens.

Before leaving the subject of solid particle erosion it is useful to discuss repair procedures. The various service shops that offer repair service to the turbine industry have become very skilled in their ability to restore eroded partitions to their original shape by adding weld metal and then finishing the surface to match the original profile. This is an extremely tedious process and, while a skilled operator can do an excellent job, a careless operator may not. Solid particle erosion is most common on the first stage of the turbine where the blades are short and with small throat areas. These small throat areas make it extremely difficult to see the final blade surface upstream from the trailing edge and the pressure surface may be left in a less than perfect condition.

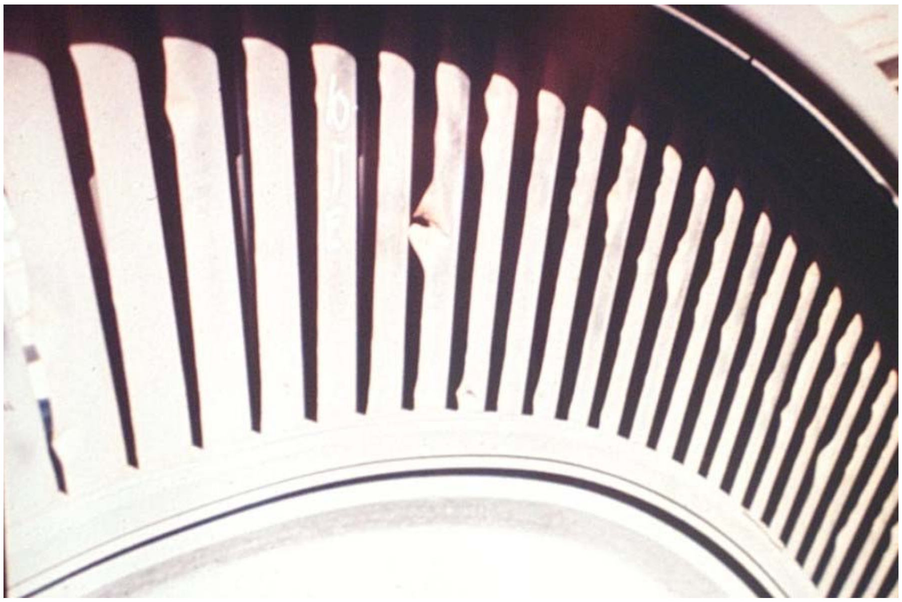
The author has seen instances where there was a significant step in the profile surface upstream from the tailing edge on the pressure surface. This, of course, may result in a poorer stage efficiency than if the erosion had been left unrepaired. There also have been instances where the HP turbine efficiency improved with time following a return to service with repaired first stage nozzles. This resulted from the fact that the upstream pressure surface was left in a rough condition and subsequent erosion gradually smoothed it out and improved the stage efficiency.

The message here is that high quality repairs are possible, but check the result to be sure that is what you got.

Mechanical Damage

Mechanical damage, of course, can come in many forms. Figure 3 is one. Figure 4 is another example.

Figure 4



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The missing blade cover, as shown in Figure 3, is one of the many kinds of foreign objects - bolts, nuts, wrenches, etc. - that can lodge in, and protrude from, the stationary blading and cause the type of damage shown in Figure 4.

As with solid particle erosion, the user segregates the total number of blades into four groups and then selects a type of deformation that is typical for each of the groups. The eSTPE program makes available five different type of deformation: half round, half ellipse, square, rectangle, and triangle. The user needs to select the type that best matches the situation being evaluated and then enter typical height and depth dimensions. Once this information has been entered, the program will proceed to calculate an average area change for the stage, dealing with stationary and rotating rows separately, and an appropriate damage coefficient which will modify the stage velocity coefficients.

Again. as with solid particle erosion, the program will perform a velocity diagram calculation for the stage and determine the impact of the damage on stage efficiency and output.

It should be noted that for stages close to the inlet of the HP turbine, changes in the stage flow areas will have an impact on the total turbine flow as well as the individual stage efficiency. For example, solid particle erosion usually results in an increase in turbine output. This is so because, if the erosion occurs on the first stage which is quite common, the increased flow area will allow an increased steam flow into the turbine. The power output from the first stage will be diminished because of the erosion but this will be more than offset by the increased output on all other stages resulting from the increased steam flow.

Erosion or other area changes on stages in the intermediate and low pressure turbines will have little or no effect on the total turbine flow. The impact of area change in these casings is to change the energy distribution on the stages, which normally results in a decrease in overall turbine efficiency.

Conclusion

As with the degradation described in the first two parts of this series, "Leakage Control Devices" and "Surface Finish and Deposits", evaluating the impact of observed degradation is a sophisticated process that can be dealt with quite easily if you have a carefully designed computer program that will define the characteristics of the turbine you are evaluating and then carry out the necessary calculations to determine the impact of the identified degradation. eSTPE is such a program. It has been in use by power plant owners and Encotech audit personnel for about fourteen years and has demonstrated that it will accurately predict the impact of damage identified during an internal inspection.