Steam turbines service and solutions to reduce unavailability, improve flexibility and extend unit life

Gabriele Porta, Luca Corso and Marco Cioffi

In recent years the radical change in market demand introduced new challenges to steam turbines maintenance activities. The last experiences gained during inspections, with the operating statistics of individual components, have allowed to take steps forward in developments both in terms of components design and calculation of Equivalent Operating Hours (e.g., taking into account the contribution due to thermo-mechanical fatigue). The objective is to keep the aging of individual components under control, plan the preventive necessary actions to be done and meet new operational needs.

Return of experience from maintenance activities of reaction type RT & MT series steam turbines reported the High Pressure valves as the critical components in terms of maintenance interval limitation. To reduce unavailability and improve flexibility, upgrades have been developed for both High Pressure Stop Valve (model HSSV) and High Pressure Control Valve (model HSTVRC). These, together with the further applicable upgrades on the other main steam valves, based on the specific models, support the harmonization between Gas Turbine and Steam Turbine maintenance plans.

Moreover, to reduce the risk of forced outages and unscheduled extension of the overhaul time period caused by unexpected findings, RADAX (RADial-AXial) stage, Ansaldo Energia´s patented solution on High Pressure and Intermediate Pressure inner casings without control stage and wire wooling solutions on rotors made of material with high Chromium content have been developed.

Last but not least, based on outcomes of both calculation outputs and several service experiences, more detailed inspections and preventive reworking of rotors most stressed areas have been considered, planned and carried out in order to extend their service life as exposed to a combination of creep and Low Cycle Fatigue (the latter increased during last years).

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1.1 High Pressure Control Valve & Stop Valve upgrades

Concerning High Pressure Stop Valve (HP SV) upgrade model HSSV, main requirement in operation of this valve is the rapid and safe closing. During start up, HP Stop Valve must open and any valve stuck in the closed position must be avoided due to the impact on unit availability.

Operational experience has shown that, under certain conditions, the stop valve type HSSV can stick in closed position. This behaviour is typical during hot start-ups: when this occurs, start up of steam turbine is delayed due to valve head-to-seat sticking. In some cases the seat pulling out has been experienced with consequent extended valve unavailability.

According to Ansaldo Energia´s experience, an upgraded design has been developed to prevent stop valve head sticking as well as diffuser displacement.

Main modifications are (see Figure 1):

- bolted seat instead of thermal shrink fit assembly;
- diffuser axial fixing due to valve strainer;
- seat angle modification on valve head;
- prestroke guide bushing modification.

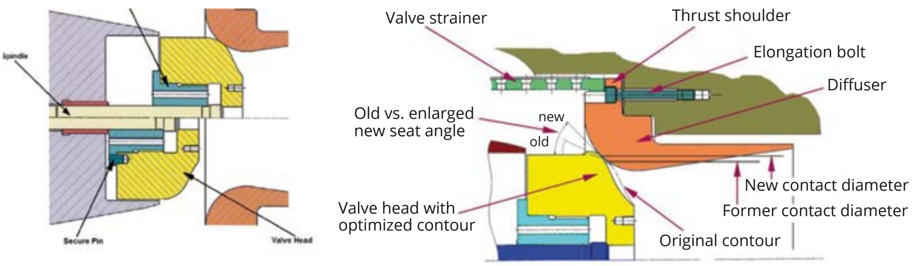

Fig. 1. HP SV upgrade.

To apply this upgrade the main activities are:
- upgraded spares supply (valve head, spindle, pilot valve, oversized seat, bolts);
- valve casing machining;
- oversized seat machining:
- strainer machining or replacement;
- valve assembly and final check.

The described upgrade is a standard design for new units.

With reference to the control valves installed in H11RC valve blocks (HSTVR 160), they have been conceived specifically for combined cycle application and intended for being operated in the fully open position for most of the time (sliding pressure operation). But as a result of the new operational mode occurred in the recent years (low load), these valves were called to throttle main steam and to operate at low lifts for extensive period of time. In heavy lamination conditions, related to low load operational mode, steam forces can generate vibrations on valve internals and, in the long-term, wear and damage on the components. The results of which can lead to steam leakage and sticking of the valve stroke together with premature aging of the internals (wear and tear).

Return of experience from sites identified the High Pressure Control Valves (HP CV) as the critical component in terms of maintenance interval limitation.

To overcome the problems related to extended time on heavy throttling, Ansaldo Energia developed new design of valve internals (see Figure 2). The design of these new internals is derived from a heavy-duty design used for large fossil power plants.

In the new design, the spindle and valve head are no longer a single piece, but an assembly with a pilot and main stroke. Two hard-faced guide sleeves support the valve head for improved stability. Pilot valve assures a better and stable operation at low load. The leak tight pilot and main stroke eliminate the need for piston rings, resulting in reduced wear during throttling operation. The improved valve head stability, combined with the pilot stroke, significantly improves throttling capability compared to the original design. Moreover, the valves seal rings will be metallic and no more in soft material like graphite, increasing the life of the seal system.

The activities to be done to install this upgraded design are:
- supplying and assembly of new internals;
- supplying new actuator;
- new steam seals line to be supplied and welded on site;
- new oil lines to be supplied and welded on site;
- implementation on DCS of new valve characteristic curve.

The new valve internals can be fitted inside the existing valve casing, which does not need any remachining (drop-in solution) except for the additional holes on valve body.

Both these described upgrades of HP main steam valves can be carried out during a scheduled valve or minor inspection without affecting the total duration of the overhaul.

1.2 Radax vanes patented upgrade

Several findings on High Pressure (HP) and Intermediate Pressure (IP) sections of the reaction turbines without control stage and with a radial inlet scroll had shown that the first stationary rows (the so called RADial AXial – and so Radax – stationary rows) suffer for bending and cracking, resulting from a combination of effects, like hindered thermal expansion, exposure to high temperature and heavy cycling.

Besides crack like indications in the transition area between blade airfoil and shroud or root, bending and deformation of airfoil or shroud as well as ruptured vanes have been observed.

If not addressed, crack initiation might in some cases propagate to a rupture and, in a worst-case scenario, finally lead to a loss of individual vanes. In such an event, consequential damage to the downstream blading cannot be excluded. In Figure 3 Radax identification and typical findings are presented.

Root Cause Analysis (RCA) suggests that steam temperature, exposure time, operation mode (connected to the casing ovalisation) and water chemistry are the main contributors. According to Ansaldo's experience, the most likely root cause of the above mentioned findings and potential cracking is Low Cycle Fatigue (LCF) damage, due to additionally introduced thermo-mechanical load. This can happen, when the gap be-

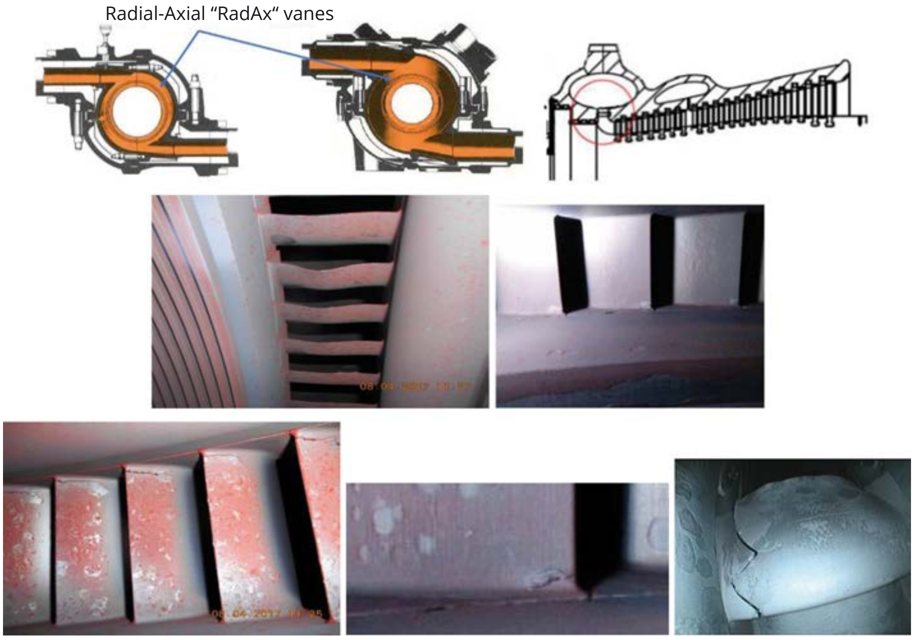

Fig. 3. Radax vanes identification and typical findings

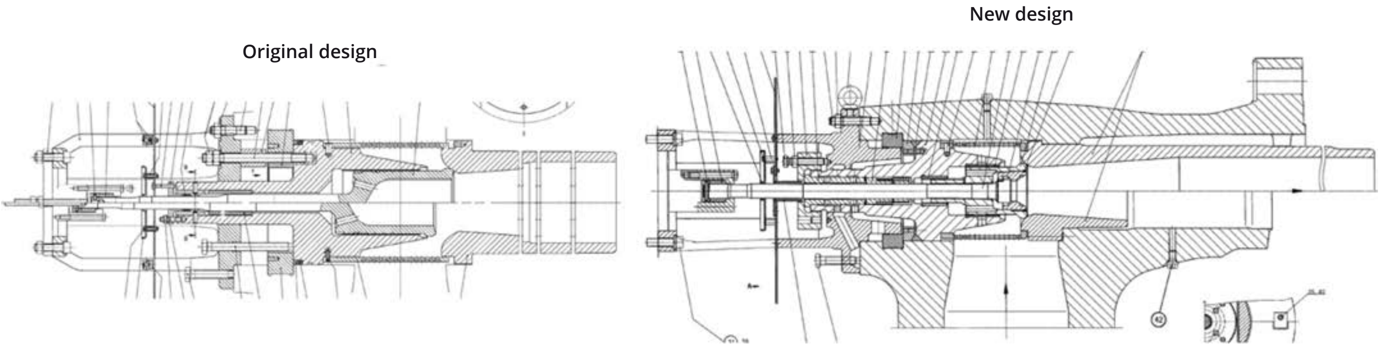

Fig. 2. HP CV upgrade.

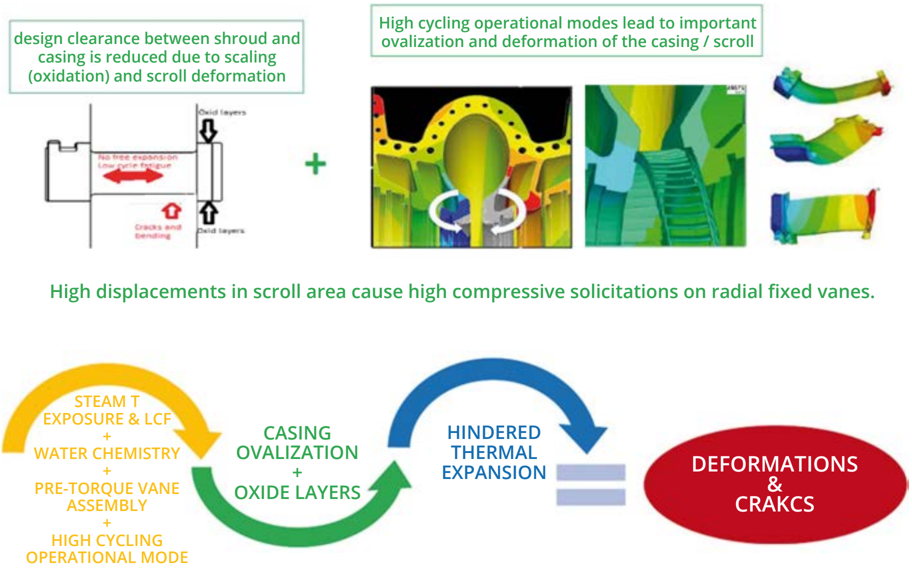

Fig. 4. Radax vanes damage mechanism.

tween shroud and casing is closed due to scaling and the casing deformation, so the blade shroud is strongly clamped into the casing groove. The build-up of oxide layers strongly depends on the steam temperature over its exposure time and also on the water chemistry.

In Figure 4 Radax vanes damage mechanism is shown.

In order to reduce the risk of forced outages and unscheduled extension of the overhaul time period caused by unexpected findings on the Radax stage, Ansaldo Energia developed a patented solution, widely applied and verified: an improved design of the Radax vanes allowing a free thermal expansion of stationary blades – i.e. vanes – into the inner casing, discarding the original concept of assembly of individual vanes.

In the new, patented solution, all vanes are machined from an integral ring and split into two halves after machining (see Figure 5). Such solution is a standard design on new steam turbines and it is retrofitable in the installed fleet (applied during maintenance activities to the existing casings affected by permanent deformation).

The steam path will not be affected by this solution, since the profile matches the original steam path design (profile, number of passages, throat area).

The new solution overcomes all the issues of single vanes fitting (clearances, torsion, contact) and allows a proper operation of the bladed ring within its groove (in terms of expansions and mechanical integrity).

The scope of work required to implement the upgrade is:

- inner casings (HP and IP, whichever is upgraded) are NDT inspected, dimensionally checked and the Radax original stage is debladed;
- new grooves are subsequently machined and inspected;
- the bladed ring is fitted with specified clearances and both half rings are secured with pins.

Activity can be performed on site, by a portable CNC boring machine.

In Table 1 it is reported our reference list updated at 2023. The machining activities were applied both on site or on workshop, and the best choice can be defined based on schedule optimization in case of both HP and IP inner casings have to be upgraded or based on specific context, for example to avoid the shipping of the casings outside the plant.

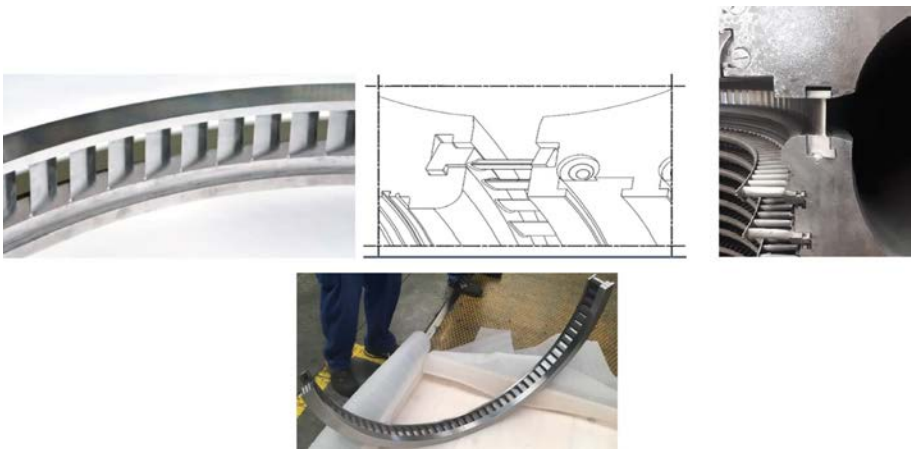

Fig. 5. Radax vanes patented solution.

Based on an extensive experience on this matter, Ansaldo Energia considers the implementation of the patented rings as the only approach to be able to completely overcome the Radax vanes issue.

1.3 Rotors integrity

1.3.1 Wire wooling – high Cr rotors upgrade with anti-wooling coating

Precondition for wire wooling damage is the material of the HP and IP rotors. This issue could potential afflict all the steam turbines rotors made of materials with an high Chromium (Cr) content affecting the working area of the bearings and oil baffles. For the working area of the bearings an anti-wooling coating has been applied for years in the new units, but since in recent years we observed an increase of this type of damage also on the oil baffles area, a dedicated service repair solution was necessary to be developed for this specific not covered area.

Apart the precondition, wire wooling is a combination of different promoting factors like dirt and foreign particles inside bearing pedestal and lubricating oil. Focusing on the oil baffles area, sources of dirt and foreign particles mainly are the insulation and the uncaring of the lubricating oil condition.

Another promoting factor is the vacuum in the oil tank. It is easy to understand that too high values of vacuum promote the suction of the environmental dirt and dust inside the pedestal.

The last but not least promoting factor is the overheating of the area which could be caused by the insulation distance (insulation too close to the pedestal is a barrier for air circulation and heat removal from convection) or by steam leakages from the glands.

The combination of the high Cr content, dirt and overheating leads to Cr Carbides formation (Cr will migrate from the rotor to the Carbon in cracked oil between oil baffle and rotor itself) creating a ring of very hard material which acts like a cutting tool starting, even in absence of shear stress, the turning of the rotor, forming a long chip which is typical of the wire wooling – even called abrasive wear – phenomenon. This phenomenon, once started, is self-sustaining, so if not identified and intercepted in time it will continue till affecting rotor integrity.

The repair solution is a low alloy protective coating to remove the prerequisite, namely the high Cr content in the rotor material. Ansaldo Energia has a qualified process which use Submerged Arc Welding (SAW) for both repair in service (both working area of the bearings and oil baffles) and preventive action in new units (working area of the bearings).

Tab. 1. Radax ring reference list.

Plant	Section	Date	OEM	Solution implemented
Spain	High pressure	2021	Alstom	Radax ring
Spain	Intermediate pressure	2021	Alstom	Radax ring
Italy	High pressure	2020	Alstom	Radax ring
Italy	Intermediate pressure	2020	Alstom	Radax ring
Italy	High pressure	2019	Ansaldo	Radax ring
Italy	Intermediate pressure	2019	Ansaldo	Radax ring
Spain	Intermediate pressure	2019+2021	Alstom	Radax ring
Spain	High pressure	2019+2021	Alstom	Radax ring
Greece	Intermediate pressure	2019	Ansaldo	Radax ring
Italy	High pressure	2021	Ansaldo	Radax ring
Italy	Intermediate pressure	2021	Ansaldo	Radax ring
Italy	Intermediate pressure	2020	Ansaldo	Radax ring
Italy	High pressure	2021	Alstom	Radax ring
Italy	Intermediate pressure	2021	Alstom	Radax ring
Belgium	High pressure	2021	Ansaldo	Radax ring
Belgium	Intermediate pressure	2021	Ansaldo	Radax ring
Netherland	High pressure	2021	Alstom	Radax ring
Netherland	Intermediate pressure	2021	Alstom	Radax ring
Chile	High pressure	2021	Ansaldo	Radax ring
Chile	Intermediate pressure	2021	Ansaldo	Radax ring
Italy	High pressure	2021	Ansaldo	New Unit with ring as per original design
Italy	Intermediate pressure	2021	Ansaldo	New Unit with ring as per original design
Italy	High pressure	2021	Ansaldo	New Unit with ring as per original design
Italy	Intermediate pressure	2021	Ansaldo	New Unit with ring as per original design
Iran	High pressure	2020	Ansaldo	New Unit with ring as per original design
Iran	Intermediate pressure	2020	Ansaldo	New Unit with ring as per original design
Iran	High pressure	2020	Ansaldo	New Unit with ring as per original design
Iran	Intermediate pressure	2020	Ansaldo	New Unit with ring as per original design
Italy	Intermediate pressure	2022	Ansaldo	Radax ring
Chile	High pressure	2021	Ansaldo	Radax ring
Chile	Intermediate pressure	2021	Ansaldo	Radax ring
Italy	High pressure	2022	Ansaldo	New Unit with ring as per original design
Italy	Intermediate pressure	2022	Ansaldo	New Unit with ring as per original design
Algeria	High pressure	2022	Alstom	Radax ring
Algeria	Intermediate pressure	2022	Alstom	Radax ring
Algeria	High pressure	2022	Alstom	Radax ring
Algeria	Intermediate pressure	2022	Alstom	Radax ring
Ecuador	Intermediate pressure	2022	ABB	Radax ring
Italy	Intermediate pressure	2021	Ansaldo	Radax ring
Italy	High pressure	2021	Ansaldo	Radax ring
Italy	High pressure	2022	Ansaldo	New Unit with ring as per original design
Italy	Intermediate pressure	2022	Ansaldo	New Unit with ring as per original design
France	Intermediate pressure	2022	Ansaldo	Radax ring
France	High pressure	2022	Ansaldo	Radax ring
Italy	Intermediate pressure	2022	Ansaldo	Radax ring
Italy	High pressure	2022	Ansaldo	Radax ring
Belgium	Intermediate pressure	2022	Ansaldo	Radax ring
Belgium	High pressure	2022	Ansaldo	Radax ring
Italy	Intermediate pressure	2021	Ansaldo	Radax ring
Chile	High pressure	2023	Ansaldo	Radax ring
Chile	Intermediate pressure	2023	Ansaldo	Radax ring

Continued on the next page.

Plant	Section	Date	OEM	Solution implemented
Italy	Intermediate pressure	2023	Ansaldo	Radax ring
Italy	High pressure	2023	Ansaldo	Radax ring
Italy	Intermediate pressure	2023	Ansaldo	Radax ring
Italy	High pressure	2023	Ansaldo	Radax ring
UK	High pressure	2023	Alstom	Radax ring
UK	Intermediate pressure	2023	Alstom	Radax ring
UK	Intermediate pressure	2023	Alstom	Radax ring
Italy	Intermediate pressure	2023	Ansaldo	Radax ring
Italy	High pressure	2023	Ansaldo	Radax ring
Italy	Intermediate pressure	2023	Ansaldo	Radax ring
Italy	High pressure	2023	Ansaldo	Radax ring
France	Intermediate pressure	2023	Ansaldo	Radax ring
France	High pressure	2023	Ansaldo	New inner block with ring as per original design

The main steps of the in-service repair process can be summarized as follows:
- rotor runout reading;
- premachining of the area for SAW preparation;
- NDTs and dimensional checks;
- welding of the low alloy protective coating (anti-wooling coating);
- NDTs and dimensional checks (including rotor runout);
- Post Weld Heat Treatment (PWHT);
- NDTs and dimensional checks (including rotor runout);
- final machining to restore the geometry as per design and final NDTs and runout check.

In order to avoid the wire wooling damage mechanism in the oil baffles area it is in any case crucial to act on the contribution factors reducing the presence of foreign particles and dirt as much as possible, taking under control the vacuum level in the oil tank and guarantee a proper placement of the insulation around the pedestal area, assuring the minimum distance between insulation and pedestal, respecting the thermal insulation drawing to have the proper air circulation (thermal convection) and to reduce the risk of suction of pollutant coming from the insulation itself. For example, heat shields has been developed and shall be implemented to guarantee the proper placement of the insulation, reducing the risk of overheating.

As a reference, a relevant case study was selected, related to a 130 MW MT15 reaction type turbine (2 cylinders unit) manufactured by Ansaldo Energia. A wire wooling at medium stage was detected on all the HP rotor oil baffles working area as it is possible to see in the Figure 6 (pedestal number 1 and number 2), during an unplanned outage in 2022. Cracked oil and carbrides residues are very clear on the oil baffle. The maximum depth of the damage in the worst point was 3.4 mm for a width of around 40 mm. Ansaldo Energia performed the rotor repair in a local workshop on line during the major overhaul carried out in 2023.

On the right side of the Figure 6 the most interesting phases of the repair are represented:
- machining of the damaged area for welding preparation;
- SAW welding;
- local monitored PWHT;
- NDTs;
- final machining to restore the original geometry.

The repair has been done in the planned outage window without having impacted on the total duration of the major overhaul.

A dedicated solution for service applications was developed to apply the low alloy protective coating directly onsite. In this case all the machining steps will be done on special portable lathe or with orbital lathe machine, the application of the welding overlay will be carried out by portable SAW machine, PWHT can be performed by portable heat treatment machine and NDTs are managed by service specialists.

The run-out test will be always certified before releasing the rotor for operation since the monitoring of the same during the whole process is crucial.

Fig. 6. Wire wooling damage on rotor oil baffles area, online repair case study.

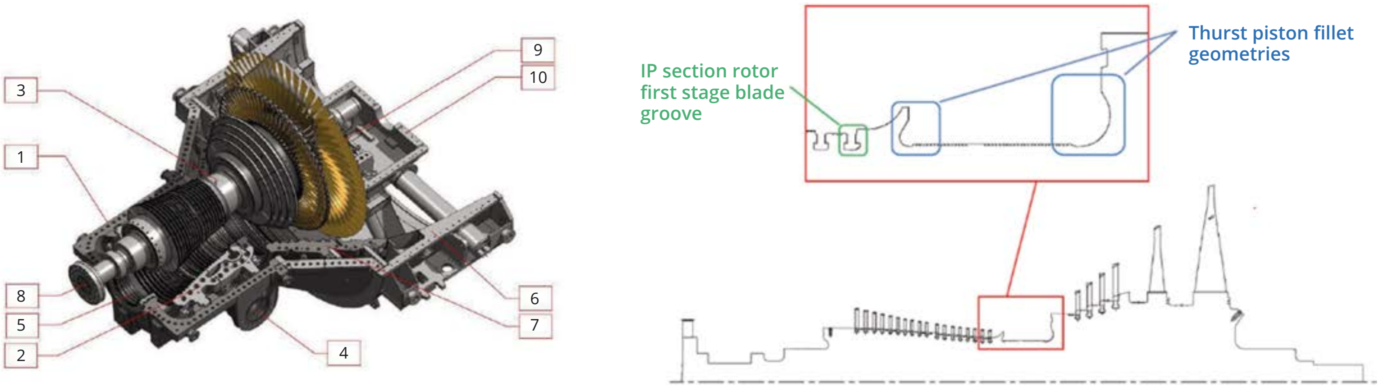

Fig. 7. Wire wooling damage on rotor oil baffles area, online repair case study.

1.3.2 Rotors inspection and reworking

Concerning rotors integrity and so their service life, it is important to focus the attention on the most critical areas of the rotors, since in recent years we observed a growing of cracked rotors cases due to the increasing in cycling operation and the general aging of the steam turbines fleet.

Cycling operation and start distribution (frequent start/stop cycles, load variations, cold-warm-hot start up) are the main contributors to Low Cycle Fatigue (LCF) damage mechanism on steam turbine rotors, that may eventually lead to crack initiation and propagation, in some cases with also the contribution of creep damage. Heavier is the cycling, higher is the impact on the rotor lifetime consumption.

Several lifetime evaluations were carried out in previous years in order to allow to the steam turbine most critical components to match the new market requirements. An important outcome is related to the IP steam inlet area of Intermediate Pressure-Low Pressure (IP-LP) combined rotors, both the thrust piston fillet and the rotor first stage blade groove (see Figure 7): the thrust piston fillet and the rotor first stage blades groove are the most critical areas in terms of life consumption, for the combination of mechanical and thermal stresses.

To improve fatigue crack initiation life in the high temperature and stresses inlet regions, geometry modifications have been evaluated (outcomes of calculations reviews).

The preventive reworking would not only improve the local geometry of the machined areas, but at the same time, it would remove the layer of deteriorated material (the so called skin effect, which is superficial material aged by accumulated microstructural damage), either on the thrust piston fillets than on the first stage blades groove, improving thus the fatigue crack initiation life.

Life Time Assessment study, which is a theoretical analysis to assess the nominal residual life of the rotor evaluating the cumulative damage contributions due to creep and to LCF (thanks to Finite Element Method analysis and operation history analysis), can be eventually evaluated in order to plan to reworking of the rotor critical areas geometry to reduce the risk of future rotor cracking.

Similar to the IP-LP combined rotors, also the HP and IP single flow rotors are subjected to this kind of damage mechanism, again in the first stage blades groove and main transition radii around inlet region, which are the most critical areas in terms of life consumption, for the combination of mechanical and thermal stresses.

At a certain number of cycles (or equivalent cycles to be evaluated in cooperation with Ansaldo Energia, considering also the specific rotor history) an inspection of the first stage blades groove in HP and IP single flow rotor is strongly recommended along as an accurate check of all the transition radii (which in any case is part of the standard inspection plan). Inspection would require unit opening, complete first blades stage removal and replacing and an accurate cleaning and checks of the areas where the severe mechanical thermal stress is expected. Moreover, the developed geometry modifications can be applied as a preventive action to improve fatigue crack initiation life.

Regarding the first stage blades groove, asymmetrical groove has been introduced since 1996 as a standard design to replace the symmetrical one and since then, Ansaldo had adopted this design feature on all new units and, when required, on in-service units, as part of the technology license either on HP than on IP and IP/LP combined rotors.

The asymmetric groove brings to an average improvement in terms of LCF damage of

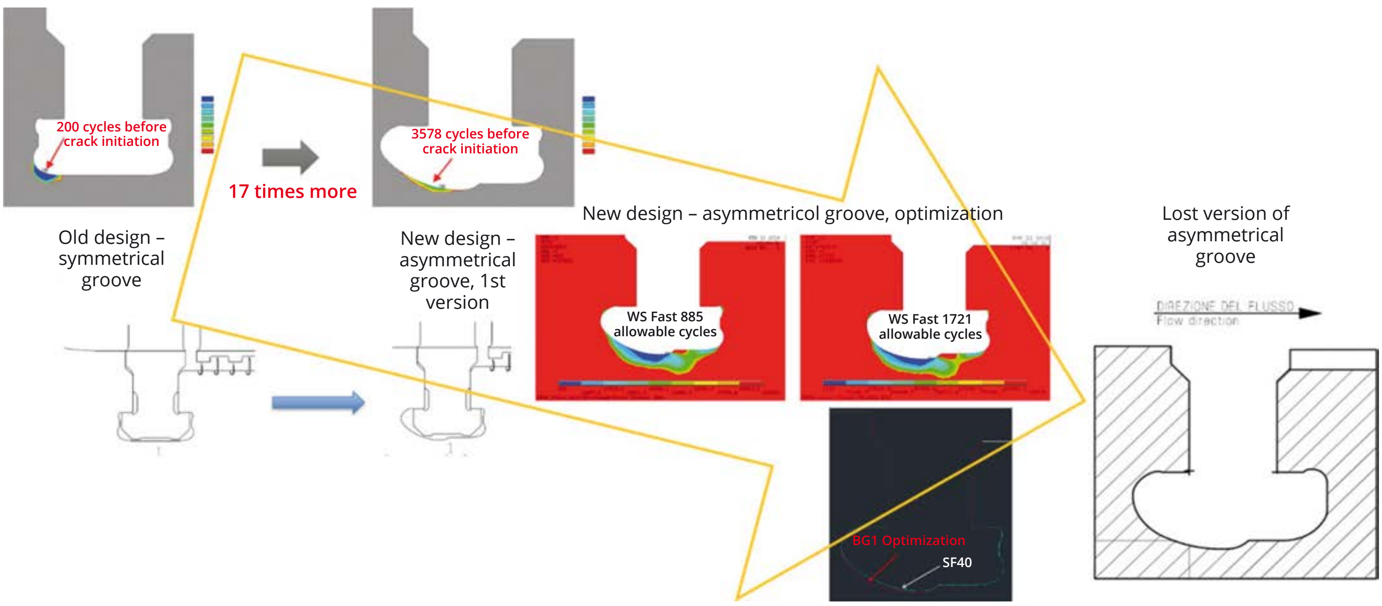

Fig. 8. 1st stage blades groove history and evolution.

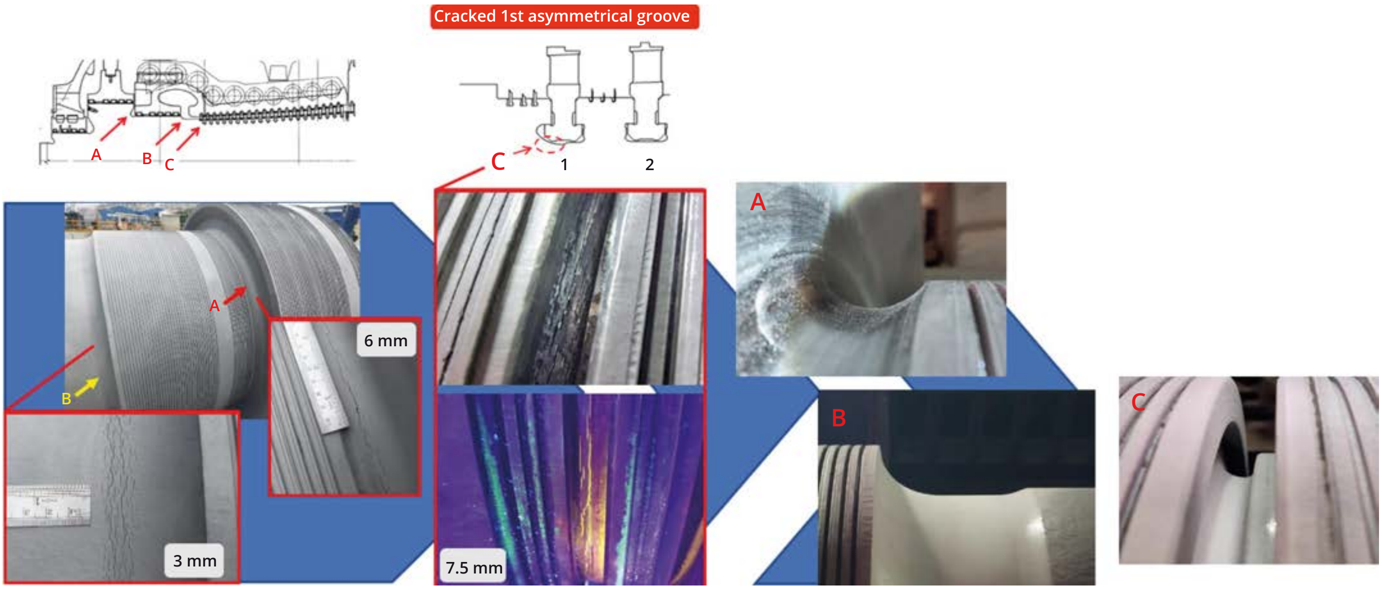

Fig. 9. Single flow cracked rotor, case study.

around 17 times (comparison with same boundary conditions), resulting in a Life Extension effect of the rotor.

Moreover, in the last few years, an improved design of the first stage asymmetrical blade groove has been developed by Ansaldo Energia. This last version of the asymmetrical groove was developed in order to improve once more the fatigue crack initiation life (comparison with same boundary conditions).

In Figure 8 the 1st stage blades groove history is summarized based on Finite Element Method simulations results.

Therefore, in case of symmetrical groove design, it is mandatory to rework the groove at first useful occasion to apply the last asymmetrical groove design. In case of an already asymmetrical groove, but of the first design, an inspection and/or preventive reworking could be necessary, based on unit history.

A relevant case study (one of the worst, but we had many cases of cracked rotors in the last years), can be seen in Figure 9, involving a single flow HP rotor of Ansaldo 94 MW reaction type turbine. During the last overhaul several cracks in different places with different depth were found, and not only on the rotor fillets, but also in the groove of the first stage blades. This rotor in the past was bowed due to water ingress and it was performed straightening by hot spotting and stress relief heat treatment. So with this history and these extensive cracks it was clear that the material was at the end of its life. The solution was to supply and install new rotor, but based on new rotor unavailability it was defined a mitigation plan to allow temporary operation waiting for the new rotor. The mitigation plan basically consisted on:

- cracks removal, new profiles definition and recountouring, which was performed on site online with portable lathe;
- modification of start-up curves;
- vibration data monitoring, especially in terms of modification of 1st critical speed, which based on our experience is one of the most important parameter to be monitored in order to understand if there is an advanced stage crack not uniformly distributed along the circumference in the rotor body (it is the last signal to prevent rotor failure during operation)

2 Summary

The presented solutions to reduce unavailability, improve flexibility and extend life of reaction technology steam turbines were developed starting from our service returns of experience. They are object of Technical Information Letters (TILs) issued by Ansaldo Energia service engineering department and shared with the customers through our project management team where there are contracts of maintenance in place or by our sales and technical teams during customer presentation, offer preparation or outage scope of work definition.

With reference to the topics here presented, the relevant TILs are:

- TIL1176 – SH Stop Valve internals upgrade;
- TIL1177 – SH Control Valve internals upgrade;
- TIL1265 – IP/LP rotor inspection and reworking;
- TIL1286 – HP & IP single flow rotor inspection and reworking;
- TIL1264 – Wire wooling, high Cr rotors upgrade with anti-wooling coating.

Kurzfassung

Wartung und Lösungen zur Reduzierung von Ausfallzeiten, Verbesserung der Flexibilität und Verlängerung der Lebensdauer von Dampfturbinen

In den letzten Jahren hat die radikale Veränderung der Marktnachfrage neue Herausforderungen für die Wartung von Dampfturbinen mit sich gebracht. Die jüngsten Erfahrungen aus Inspektionen und Betriebsverläufen einzelner Komponenten haben es ermöglicht, sowohl bei der Konstruktion von Komponenten als auch bei der Berechnung der äquivalenten Betriebsstunden (z.B. unter Berücksichtigung des Beitrags der thermomechanischen Ermüdung) Fortschritte zu erzielen. Ziel ist es, die Alterung einzelner Komponenten einzugrenzen, die erforderlichen vorbeugenden Maßnahmen zu planen und neuen betrieblichen Anforderungen gerecht zu werden.

Erfahrungen aus der Wartung von Dampfturbinen der Serien RT und MT haben gezeigt, dass Hochdruckventile die kritischen Komponenten hinsichtlich der Begrenzung der Wartungsintervalle sind. Um Ausfallzeiten zu reduzieren und die Flexibilität zu verbessern, wurden Upgrades sowohl für das Hochdruck-Absperrventil (Modell HSSV) als auch für das Hochdruck-Regelventil (Modell HSTVRC) entwickelt. Zusammen mit weiteren Upgrades für andere Hauptdampfventile, basierend auf spezifischen Modellen, unterstützen diese die Harmonisierung zwischen den Wartungsplänen für Gas- und Dampfturbinen.

Um das Risiko von Zwangsstillständen und ungeplanten Verlängerungen der Wartung aufgrund unerwarteter Befunde zu verringern, wurden außerdem die patentierte RADAX-Stufenlösung (RADial-AXial) für Hochdruck- und Mitteldruck-Innengehäuse ohne Regelstufe sowie Drahtwoll-Lösungen für Rotoren aus hochchromhaltigem Material entwickelt.

Nicht zuletzt wurden auf Grundlage der Berechnungsergebnisse und mehrerer Serviceerfahrungen detailliertere Inspektionen und vorbeugende Nachbearbeitungen der am stärksten beanspruchten Bereiche der Rotoren in Betracht gezogen, geplant und durchgeführt, um deren Lebensdauer zu verlängern, da sie einer Kombination aus Kriechen und Low Cycle Fatigue (letztere hat in den letzten Jahren zugenommen) ausgesetzt sind.

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t +49 201 8128-266
e vgbe-wasserdampf@vgbe.energy

Information on all events with exhibition
Auskunft zu allen Veranstaltungen mit Fachausstellung

t +49 201 8128-310/-299
e events@vgbe.energy

Updates **www.vgbe.energy**

Wasseraufbereitung
vgbe | Seminar

20. und 21. März 2024
Velbert, Deutschland

Kontakt
Eugenia Hartmann
t +49 201 8128-266
e vgbe-wasseraufb@vgbe.energy

Flue Gas Cleaning 2024

Workshop

22 and 23 May 2024
Frankfurt a.M., Germany

Contact
Ines Moors
t +49 201 8128-222
e vgbe-flue-gas@vgbe.energy

Chemie im
Wasser-Dampf-Kreislauf

vgbe | Seminar

13. und 14. November 2024

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Eugenia Hartmann
t +49 201 8128-266
e vgbe-wasserdampf@vgbe.energy

Offshore Windenergieanlagen – Arbeitsmedizin 2024

Fortbildungsveranstaltung

6. und 7. September 2024
Emden, Deutschland

Kontakt
Dr. Gregor Lipinski
t: +49 201 8128 272
t +49 201 8128-272
e gregor.lipinski@vgbe.energy

Immissionsschutz- und Störfallbeauftragte 2024

Fortbildungsveranstaltung

26. bis 28. November 2024
Höhr-Grenzhausen, Deutschland

Kontakt
Stephanie Wilmsen
t +49 201 8128-244
e vgbe-immission@vgbe.energy

Exhibitions and Conferences

E-world energy & water

20. bis 24. Februar 2024
Essen, Deutschland

www.e-world-essen.com

Enlit Europe 2024

22 to 24 October 2024
Milan, Italy

www.enlit-europe.com/

56. Kraftwerkstechnisches Kolloquium

8. und 9. Oktober 2024
Dresden, Deutschland

https://t1p.de/tud-kwt (Kurzlink)