Experiences in manufacturing of forgings for power generation application

G. Zeiler, R. Bauer, A. Putschoegl

Sufficient available energy is the precondition for a high standard of living in each country. This fact calls for the need of an appropriate number of power generation plants with improved technologies to achieve higher efficiency combined with reduced environmental pollution – a challenge, which is not only aimed to the power station manufacturers but also to the producer of forgings who have to manufacture components from more and more higher alloyed materials and for this reason more complex manufacturing processes.
This paper reports about experiences in the fabrication of forged components for gas and steam turbine application up to achieved mechanical properties and NDT results, focused on the newer materials with improved high temperature capability, and here the steels of the 9-12% Cr class developed in the frame of the European Cost research programme.

KEYWORDS: forgings for power generation, melting processes, forging, 10% Cr steels, properties, cost programme, FB2 material

INTRODUCTION

The continuous trend towards more economic electricity production in parallel with reduced environmental pollution can only be sustained by improving the thermal efficiency of power generation plants. The efficiency is increased by raising the temperature and also the pressure of the steam which finally results in the need for improved materials for the boiler and turbine design.
Since many years Boehler Edelstahl GmbH & Co KG is a premium supplier of forged components for the power generation industry, e.g. discs, centre shafts, turbine shafts, shaft components and accessories for gas and steam turbines. Based on a complete range of special steelmaking equipment consisting of an electric steel plant (electric arc furnace, AOD converter, secondary metallurgy equipment), a special melting shop with vacuum and re- melting facilities (VIM-VAR, ESR, PESR), a 52 MN hydraulic forging press and the R&D support of FEM modelling to achieve a uniform deformation, Boehler is in a good position for the manufacture of high-quality forgings, which are further processed in downstream facilities for heat treatment, machining and testing.
Our customers are counted among the most important manufacturer of steam and gas turbines such as Siemens, Alstom and licensees.
From the material side Boehler is manufacturing all the typical steels introduced in energy engines application so far but more or less focussed on higher alloyed steels (Figure 1).
Those higher alloyed steels are specifically the 9-12% Cr class, developed in the frame of the European Costresearch programme where Boehler Edelstahl is participating since 1987, starting with Cost 501. It is understood that Boehler plays an active role in these research programmes by the manufacture of not only experimental heats, but also trial rotor shafts.
In the following manufacturing and testing of forgings for gas and steam turbines are described with the focus on 10% Cr steels Cost E and F but also the first experiences for the Boron alloyed steel FB2 manufactured under production conditions.

FORGINGS FOR GAS TURBINES

There is a relatively wide range of forgings for gas turbine components, starting with the main product as discs for the compressor and the turbines, turbine rings, followed by front, centre and rear end hollow shafts, tie rod and nuts. Materials used so far are the 3 - 3,5% NiCrMoV steels which have been improved

FIG. 1
Materials for Gas and steam turbine components.
Materiali per componenti di turbine a gas e a vapore.

MATERIALS		ANALYSIS [wt.%]												
DIN	Böhler	C	Si	Mn	Cr	Mo	Ni	V	Co	W	Al	Nb	N	B
26NiCrMoV 11 5	V116	0,30	0,06	0,30	1,50	0,40	2,90	0,10			<0,010			
26NiCrMoV 14 5mod (Super Clean)	V128SA	0,30	<0,03	<0,04	1,70	0,40	3,70	0,10			<0,010			
30CrMoNiV 5 11	D102	0,32	0,10	0,80	1,30	1,10	0,65	0,30			<0,010			
X20CrMoV 12 1	T550	0,22	0,30	0,70	11,50	1,00	0,50	0,30			<0,015		0,030	
X12CrMoWVNbN 10 1 (COST E)	T506	0,12	0,10	0,45	10,30	1,06	0,75	0,18		0,90	<0,010	0,050	0,050	
X12CrMoVNbN 10 1 (COST F)	T507	0,12	0,10	0,50	10,30	1,50	0,60	0,18			<0,010	0,050	0,050	
X13CrMoCoVNbB 9 1 (COST FB2)	T558	0,13	0,10	0,35	9,50	1,50	0,15	0,25	1,30		<0,010	0,060	0,020	0,010

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substantially over the last two decades and the 10% Cr Cost E. In case of the 3 - 3,5% NiCrMoV steel a super clean version have been created to avoid or minimise long term embrittlement which allows higher operating temperatures and makes the steel useable for service applications up to 480 to 500°C [1]. This steel contains very low percentages of residual elements including sulphur and phosphorus, and the contents of aluminium, silicon and manganese is also very low. The challenge for the metallurgist in melting such a steel is to deoxidize the melt without using deoxidizers such as aluminium, silicon or manganese, to achieve the required low contents in this elements on the one hand and to obtain a high cleanliness on the other hand.
Boehler solved these problems by applying a ladle metallurgical process based on diffusion deoxidation. For this process it is necessary to provide a slag with extremely low iron oxide activity for the promotion of deoxidation. Furthermore the slag has also maintain a low alumina activity to avoid aluminium pick up [2]. Forgings, especially discs and hollow shafts, out of this steel are manufactured from conventional casted ingots, forged, preliminary heat treated by normalizing, premachined and quality heat treated by austenitising at 850°C followed by tempering at 610 – 630°C depending on the required strength level of yield strength ≥ 700 N/mm² respectively ≥ 800 N/mm². After final machining and testing the parts are ready for shipment.
The more challenging material in manufacturing turbine discs and centre hollow shafts is the meanwhile well established and qualified tungsten alloyed 10% Cr-steel COST E. It was originally developed under COST 501 [3-4] for steam turbine applications as a rotor material but the results in mechanical properties and long term behaviour illustrated, that the material is also suitable for gas turbine applications. The background and requirements, which are very different to those for steam engine applications, have already been reported [5].
During the last years Boehler Edelstahl Open Die Forge has got a lot of experience in the manufacturing of larger forgings in highly alloyed steels. Many rotor forgings, discs and hollow shafts have been manufactured for high temperature applications and the fabrication of highly stressed heat-resistant chromium-steel forgings in COST grade E (10%CrMoWVNbN) and recently also in grade F (10%CrMoVNbN) has become common practice at Boehler. Table 1 gives the scope of the forgings produced so far. The production covers all turbine relevant components such as HP-shafts, gas turbine discs, hollow shafts and other shaft components.
To date, many disc forgings with a diameter of up to 1900mm and thicknesses from 280 to 550mm and hollow shafts with outer / inner diameters of 1400 / 980mm and a length of about 1700mm in the as-forged condition are manufactured by Boehler. Due to the high requirements on gas turbine discs the steel is melted by P-ESR process.
The principle of the process is illustrated in Figure 3.
The remelting process takes place in a leak-proof chamber similar to the VAR process. Before starting remelting, the chamber is evacuated to a pressure lower than 10 mbar and flooded successively with protective gases argon and nitrogen. The reactive slag is first melted by the use of an electric arc. Once this has occurred the normal ESR process takes place with the advantage of the total absence of oxygen in the atmosphere above the slag surface and around the electrode. In that manner no oxidation can take place and this results furthermore in a very uniform quality of the remelted steel from bottom to top of the ingot. P-ESR is the desired remelting process for components made of super clean creep resistant 10% Cr steels with reduced Si and Al contents.
After heating the ingots to forging temperature, the ingots are

FIG. 2 ***Turbine disc made of 26 NiCrMoV 14 5 mod steel, Boehler grade V128SA.***

Disco di turbina realizzato con acciaio 26NiCrMoV 14 5 (Boehler grado V 128 SA).

Product	Quantity Cost E	Quantity Cost F
GT-Discs	585	—
Hollow Shafts	173	—
HP-Shafts	76	36
Other Shafts Components	87	95

TAB. 1 ***Turbine components made of COST grade E, respect. F.***

Componenti di turbina realizzati con acciaio COST grado E e grado F.

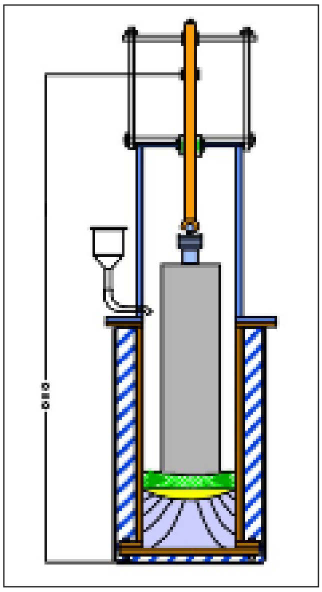


FIG. 3 ***Protective gas electro slag remelting (schematic).***

Rifusione sotto elettroscoria con gas protettivo (schema).

forged on a 52 MN forging press by upsetting followed by cogging, upsetting again and disc-forging to the final shape. Especially for the second upsetting and disc-forging the manufacturing parameters such as the forging temperature, soaking time and deformation rate are very important to ensure a defect free forging and suitable microstructure. In order to optimise the forging sequence and improve the reproducibility of the forging process, the development of the forging technology has been supported by the use of FEM modelling. Achieving a uniform deformation resulting in uniform microstructure and grain size distribution is one of the preconditions to achieve the

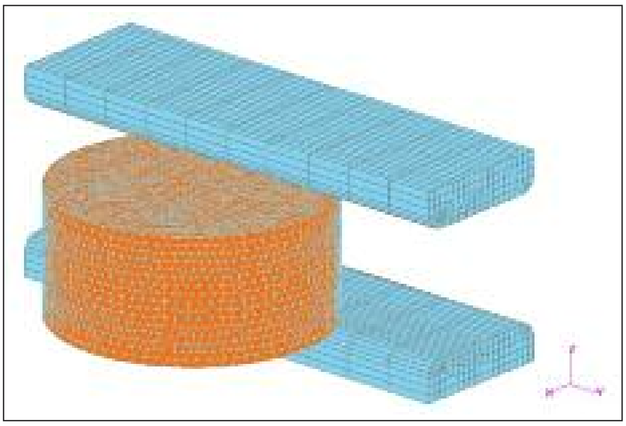


FIG. 4 ***FEM model forging a disc.***
Forgiatura di un disco simulata con modellistica FEM.

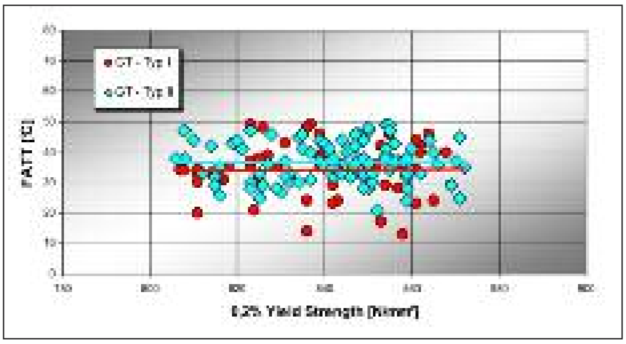


FIG. 5 ***Yield strength and FATT properties of turbine discs made of X12CrMoWVNbN10-1-1 (COST E steel).***
Valori del carico di snervamento e della FATT per dischi di turbina realizzati in X12CrMoWVNbN10-1-1 (acciaio COST E).

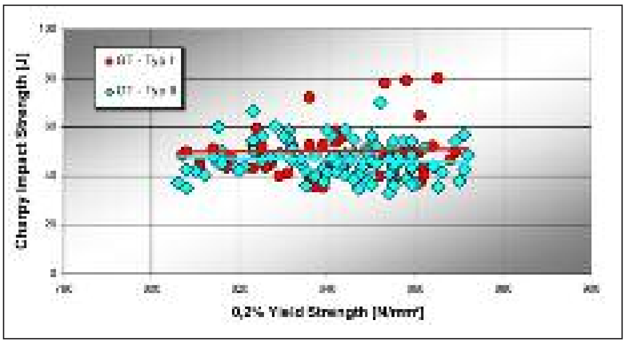


FIG. 6 ***Yield strength and Charpy Impact properties of turbine discs made of X12CrMoWVNbN10-1-1 (COST E steel).***
Valori del carico di snervamento e della resilienza Charpy per dischi di turbina realizzati in X12CrMoWVNbN10-1-1 (acciaio COST E).

high requirements on mechanical properties and ultrasonic detectability. Figure 4 illustrates the simulation of a disc forging step.
When forged, the preliminary heat treatment is of great importance in order to allow optimum ultrasonic testing of the material / forgings in the quality heat-treated (QHT) condition.
Transformation in the pearlitic phase provides the necessary

FIG. 7
Hollow shaft made of COST steel E, Boehler grade T505.

Albero cavo in acciaio COST E, Boehler grado T 505.

FIG. 8 ***General view of the 2 automated US inspection equipments.***
Vista generale della stazione automatica 2 per l'ispezione a ultrasuoni.

preconditions. After pre-machining, the QHT is performed by austenitising at 1050°C followed by double tempering at 570 and 645°C to a yield strength ³ 800 N/mm^2 followed by machining for ultrasonic testing (UT), mechanical testing and final machining. Typical test results are summarised in Figure 5 and 6.
Permanent developments in the power generation plant business have led not only to increased requirements for highly stressed components and their materials, but also to improved and increased efforts in ultrasonic testing. BOEHLER Edelstahl open die forge already invested in 1999 in an automated ultrasonic inspection facility and made an investment in a second equipment in 2008.
With the second equipment conventional as well as phased array technique is available. Ultrasonic inspection is carried out with this automated equipments; a general view is shown in Figure 8.

FORGINGS FOR STEAM TURBINES

Cost E and Cost F materials

To date, many rotor forgings in different sizes and weights have been manufactured by Boehler Edelstahl open die forge, with diameters from 700 to 1180mm and shaft ends with flange diameters of up to 1800mm. In total there are more than 300 forgings now in Cost E, a combination of 1%Mo and 1%W, respectively Cost F (1,5%Mo) material (Tab. 1). At the beginning of industrial production of this steels the focus was more on Cost E; this has changed now since a customer shifted to Cost F. Both materials are qualified and allow the new generation of fossil-fired ultra super critical thermal power stations operating at live steam and reheat steam temperatures of 600°C and supercritical live steam pressures of up to approximately 300 bar [6]. The applied melting route used so far is the already mentioned P-

ESR process for smaller shaft parts for welded rotor constructions as well as the BEST process for larger rotors with ingot weights up to approximately 45 to [7]. The principle of the process is illustrated in Figure 9.
A water-cooled ring is placed at the top end of a forging ingot mould. The mould is filled with liquid steel via a bottom pouring process. Afterwards, the steel surface is covered with a slag of a special chemical composition. The above mentioned ring acts as a slag mould similar to the ESR-process. A consumable electrode is immersed into the slag, electrical energy is applied to the system, the slag is heated and the electrode begins to melt. Droplets of the melting electrode fall into the liquid pool of the solidifying ingot, compensating for shrinkage and influencing the solidification process.
Ingots produced by this process are totally free from V-segregations and shrinkage holes.
Again, as already described in the chapter for gas turbines, the ingots are heated up to forging temperature and forged on the 52 MN forging press by mainly double upsetting followed by forging to the final shape. Especially in the case when large Best ingots are needed, the manufacturing parameters such as the forging temperature, soaking time and deformation rate for the first forging steps are very important to ensure a defect free forging. For a sufficient consolidation of the BEST ingots FEM modelling was carried out to find the optimal forming parameters necessary. Figure 10 shows the simulation of a cogging step.
When forged, the rotors are also transformed in the pearlite phase, pre-machined and quality heat treated. QHT is performed by austenitising at 1050°C – 1070°C followed by double tempering at 570 and 700°C to a yield strength ³ 700 N/mm^2. Final machining and testing have to be carried out prior to shipment. Typical test results are summarised in Figure 11.
Figures 13-14 show some examples of forgings produced for the power generation industry.

Cost FB2 material

Specifically, the 9 to 12% Cr grades steels have the highest potential to meet the required creep resistance level for the critical components in steam power plants.
Under COST 501 (1983-1997) the 9-10% Cr steels E, F and B2 for use up to 600°C were developed, trial rotor forgings with body diameters up to 1200 mm were manufactured and a lot of testing work was performed on the material and creep rupture tests are still in progress [8, 9].
Cost E and F have meanwhile become standard materials for USC power plants with 580-600°C steam temperature. The trend to even higher steam conditions was the subject of the COST 522 programme (1998-2003) where the very promising properties of FB2 test material, produced by Boehler and based on B2 from Cost 501 with the addition of Co, led to an upscale to industrial heat to manufacture a trial rotor forging.
The first full size FB2 rotor forging with a final weight of 17 to was manufactured by Boehler via the Best melting route; the second one was brought into Cost 522 by Societa delle Fucine Terni / Italy producing a 52to ingot by conventional steel making method with a final weight of 28to and finally a third rotor was made by Saarschmiede via the ESR process starting with a 56to ingot

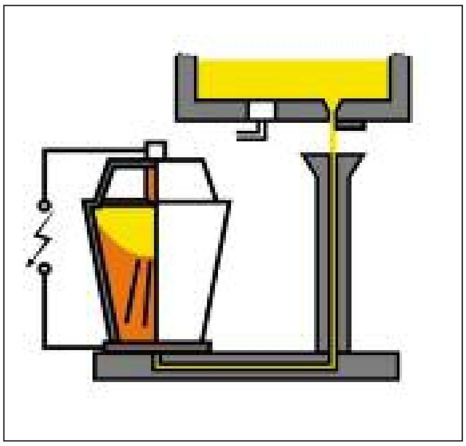


FIG. 9 ***Boehler electro slag topping (schematic).***
Topping del forno a elettroscoria Boehler.

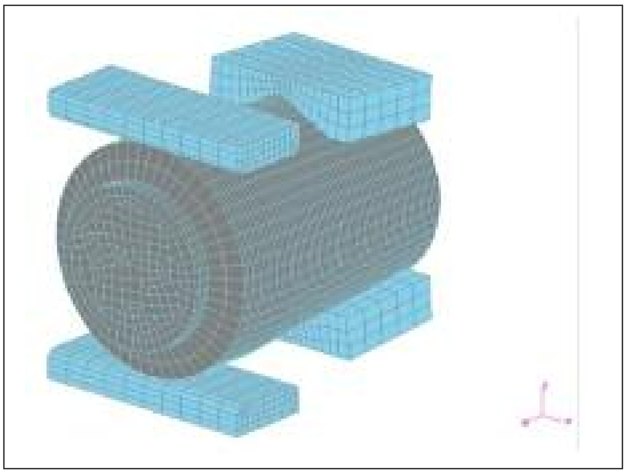


FIG. 10 ***FEM model for optimised forging steps to achieve sufficient consolidation of ingot.***
Modellistica FEM per ottimizzare i passaggi di forgiatura e omogeneizzare il lingotto.

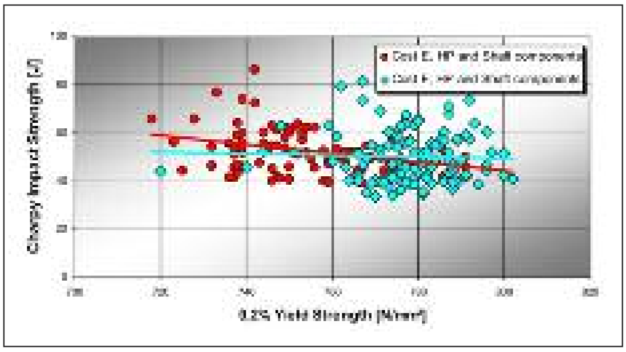


FIG. 11 ***Yield strength and Charpy impact properties of rotors and shaft ends in Cost E and F steel.***
Valori del carico di snervamento e di resilienza Charpy per rotori e terminali dell'albero realizzati con acciai COST E e F.

Steel	C	Si	Mn	Cr	Mo	W	Ni	Co	V	Nb	N	B
B2	0,17	0,07	0,06	9,3	1,55	-	0,12	-	0,27	0,064	0,015	0,010
FB2 test melt	0,13	0,05	0,82	9,32	1,47	-	0,16	0,96	0,20	0,05	0,019	0,0085
FB2 trial rotor	0,13	0,09	0,33	9,08	1,43	-	0,16	1,26	0,22	0,054	0,022	0,0076

TAB. 2 ***Chemical compositions of steels B2 and FB2.*** *Composizione degli acciai B2 e FB2.*

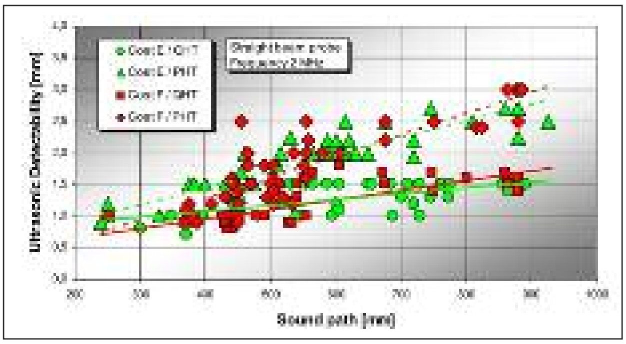


FIG. 12 ***Relationship of sound path and final ultrasonic detectability (COST E, F steel).***

Relazione tra percorso del suono e rilevabilità ultrasonica.

FIG. 13 ***Shaft component made of COST steel E, Boehler grade T505.***

Componente dell'albero realizzato in acciaio COST E, Boehler grado T 505.

and 30 to final rotor weight. Manufacturing the test melts, trial rotor forgings and test results are already reported in several papers [10-13]. Figure 15 shows an overview of the three trial rotors. While short term testing is already finished, long term creep tests are still running. The results gained so far show that all data lie in one narrow scatter band confirming the trial melt behaviour of FB2. In Figure 16 [11] the values are all above the

FIG. 14 ***Shaft component made of COST steel F, Boehler grade T507.***

Componente dell'albero realizzato in acciaio COST F, Boehler grado T 507.

rotor B2 line which is a Boron containing steel from COST 501 serving as the basis for the development of FB2.
The very good creep behaviour of steel FB2 can be attributed to characteristic microstructural features and their stability under the influence of temperature and stress.
The microstructure in the quality heat treated condition in general consists of tempered martensite, precipitates and sporadic inclusions. As can be seen in a representative transmission electron microscope (TEM) image of the alloy FB2 (Figure17, [14]), the steel indicate a very homogeneous martensitic structure with narrow martensite laths and a high dislocation density. The martensite laths are decorated with and therefore stabilised by $M_{23}C_6$ carbides which represent the dominant particle type within these steels. These particles can, to a smaller extent, also be found inside the laths.
The steel also contains up to about 1 µm large primary Nb carbonitrides which avoids grain growth during austenitisation and are stable during creep.
During the creep exposure at 600°C the microstructure changes with time due to the influence of temperature and stress. The dislocation density decreases, sub-grains form and grow, $M_{23}C_6$ particles coarsen, the martensite laths become much wider and also new phases as the Laves phase, appear.
Due to the fact that the $M_{23}C_6$ carbides are very stable in FB2 they can act as effective obstacles for dislocation movement and

FIG. 15
Under Cost 522 manufactured FB2 trial rotors, Boehler grade T559.

Rotori sperimentali realizzati nell'ambito COST 522 con acciaio FB2, Boehler grado T559.

sub-grain growth for very long times.
FB2 has a very low coarsening rate of the M23C6 particles, effected by the incorporation of boron, whose experimental detection is described in [15].
Under the influence of temperature, Laves phase also appears in FB2, but very small (0,6-0,8μm) and homogeneously distributed and therefore no negative effect on creep.
All the results gained so far indicates a comparable behaviour to the trial melt FB2 showing that the transformation of research work to large components was successfully performed and rotors / shaft parts in FB2 material have already been placed by orders for new USC power plant projects in Germany and the USA.

Experiences in manufacturing FB2 rotor forgings

Based on the experience with the Cost FB2 trial rotor forging, the manufacturing technology had to be fitted to the appropriate dimensions and the melting route was changed from Best to conventional castedingots with total weights of 22 to 28 to due to the smaller dimensions of the shafts. Till this day 4 pieces have been manufactured with delivery weights from 7 to 9,2 to and two further are under production now.
The basic manufacturing steps for the forgings were set as follows: melting the steel in an EAF, than ladle furnace followed by AOD and LF with VD, casting the ingot by bottom pouring process, homogenising, hot-forming, preliminary heat treatment, pre-machining, ultrasonic testing, quality heat treatment (QHT), machining and final testing (Figure 18).
Forging was carried out on the 52 MN forging press, consisting of cogging, upset forging twice, followed by final forging (shaping) and preliminary heat treatment (PHT) by martensitic transformation and tempering.
After pre-machining the rotors to achieve a defect-free surface, ultrasonic tests were performed to confirm the internal quality of the forgings and then the quality heat treatment for adjusting the mechanical properties was performed as follows:

- Austenitising: 1100°C / 8-10hrs / spray quenching
- Pre-tempering: 570°C / 20-24hrs / AC
- Final tempering: 700°C / 20-24hrs / AC

The target was to achieve a 0,2% yield strength of ≥ 650 N/mm².
Double annealing is performed in order to ensure a totally annealed martensitic microstructure.
The rotors were then machined and checked (Figure 19) using ultrasonic testing and to determine the minimum detectable defect size (MDDS). No defects could be found; the measured MDD's ranged from 1,5mm for a smaller part with Æ 860mm

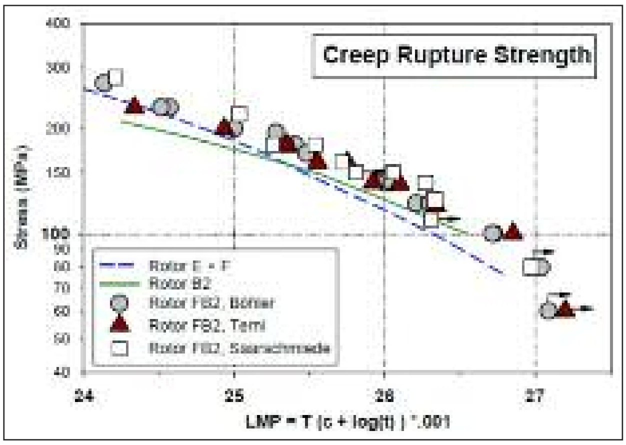


FIG. 16 ***Creep rupture strength of Cost FB2 test rotors in comparison to other Cost rotor alloys (with arrow: running specimens) [11].***

Resistenza a creep di rotori sperimentali in acciaio COST FB2 confrontata con quella di altre leghe COST per rotori (con frecce le prove ancora in corso).

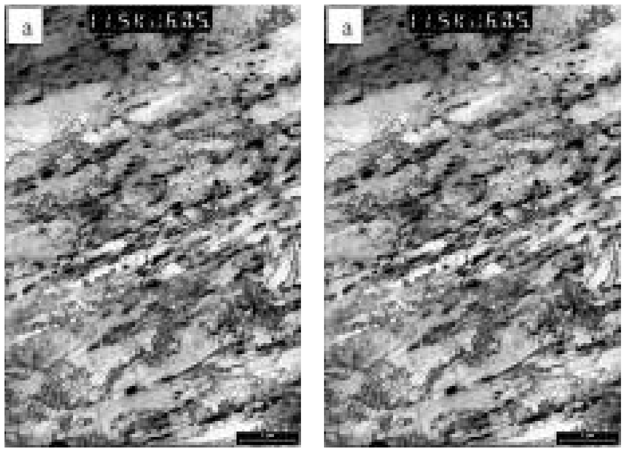


FIG. 17 ***Microstructure of FB2: After QHT (a); gauge section (b) (600°C, 100 MPa) after 56.500 hours [14].***

Microstruttura dell'acciaio FB2: (a) dopo trattamento di qualità; (b) dopo test di 56500 ore a 600 C e con carico 100 MPa.

FIG. 18
Flow chart of FB2 rotor manufacturing route.

Schema del processo di lavorazione di rotori in acciaio FB2.

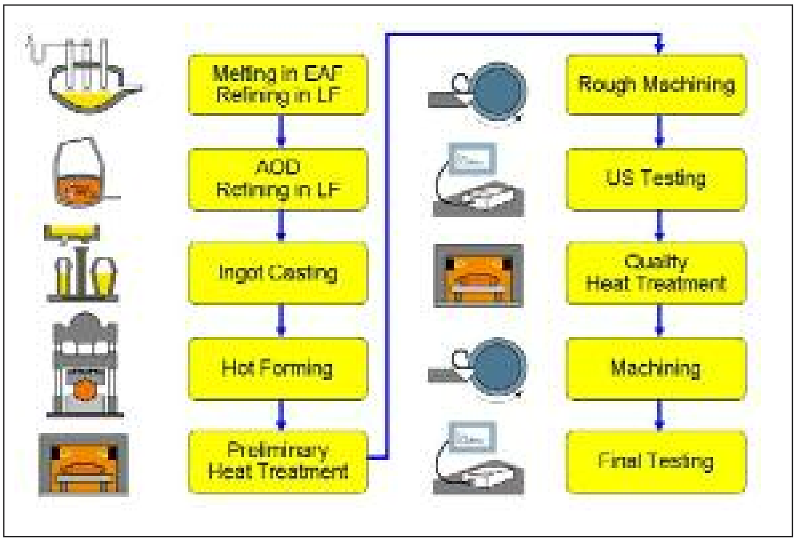


FIG. 19 ***Quality heat-treated and machined FB2 Forging; final weight 9,2 t.***

Forgiati di acciaio FB2 (da 9,2 t) dopo trattamento di qualità e tornitura.

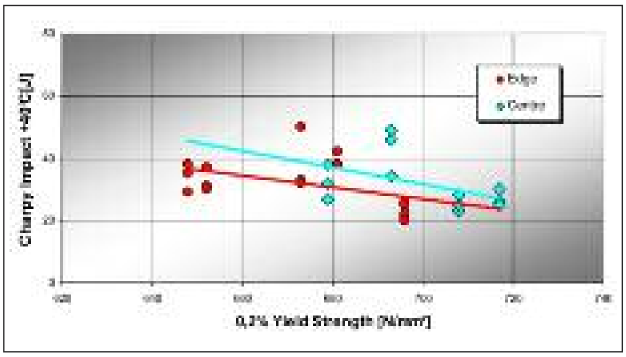


FIG. 20 ***Yield strength and Charpy impact properties of FB2 rotors.***

Valori del carico di snervamento e di resilienza Charpy per rotori in acciaio FB2.

up to 2,2mm for parts with a diameter of 1120mm respectively. There was an improvement of 0,5-0,8mm when comparing with the preliminary heat treated condition.

Test Results

All turbine shaft parts are subjected to mechanical testing in order to ensure their suitability for use.

The properties are checked at different test positions; specimens in tangential direction from the outer segments on both ends of the forging (top and bottom) and in some cases specimens were taken from a near centre test ring of 350mm in diameter and 300mm from the face end. The results of basic strength and toughness properties are summarised in Figure 20.

In addition, short-term creep tests at 600°C and 160 MPa load were performed on one shaft part at t ³ 1000h in order to compare the creep behaviour with the results achieved on the FB2 trial melt and the FB2 trial rotor forging from the Cost programme. Four test specimens in total, one from each test location, were taken in tangential direction, two from the edge and two further from the near centre position. The achieved results, plotted as a creep strain versus time curve, are shown in Figure 21. Up to 1000 hrs testing time the creep strain is on an average on the same level as the FB2 trial rotor; in two test positions even better.

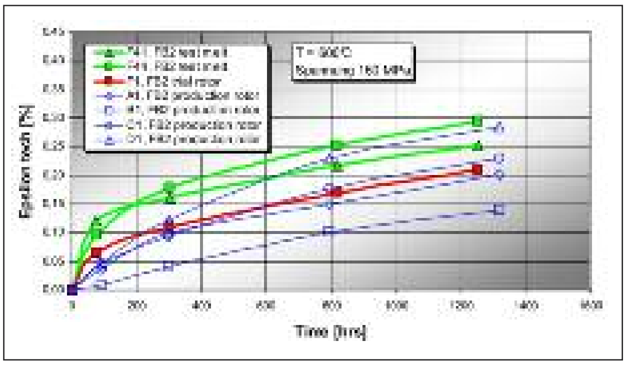


FIG. 21 ***Results of short term creep testing in comparison to FB2 trial rotor forging.***

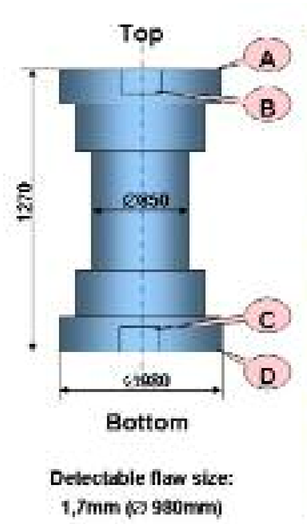
Risultati di prove brevi di creep confrontati con quelli ottenuti su un rotore sperimentale forgiato in acciaio FB2.

Metallographic examinations showed, that the microstructure in the edge as well as the near centre position is tempered martensite with a grain size of 0-1 acc. to ASTM E112 in the edge and about 00 in the near centre area. Furthermore in all sample locations examined, the microstructure was free of -ferrite and in general also free of Boron nitrides. Only one sample showed some isolated Boron nitrides of 3 µm in size.

FIG. 22

Check analysis at 4 test positions of a FB2 rotor forging.

Analisi composizionale in 4 zone di un forgiato in acciaio FB2.



		Product-Analysis [wt%] Heat P70627			
		TESTPOSITION			
		Edge		centre	
	Heat	A	D	B	C
C	0,13	0,12	0,12	0,13	0,12
Si	0,08	0,11	0,09	0,09	0,08
Mn	0,34	0,34	0,34	0,34	0,33
P	< 0,005	0,006	0,006	< 0,005	< 0,005
S	0,0009	0,0012	0,0012	0,0013	0,0010
Cr	9,37	9,24	9,25	9,29	9,14
Ni	0,12	0,12	0,12	0,12	0,12
Mo	1,41	1,40	1,40	1,43	1,40
Co	1,26	1,23	1,24	1,26	1,22
V	0,22	0,22	0,22	0,22	0,22
Nb	0,058	0,056	0,056	0,060	0,061
Al	0,009	0,010	0,010	0,010	0,010
As	< 0,005	< 0,005	< 0,005	< 0,005	< 0,005
Sb	< 0,005	< 0,005	< 0,005	< 0,005	< 0,005
Sn	< 0,005	< 0,005	< 0,005	< 0,005	< 0,005
N	0,019	0,016	0,016	0,016	0,016
Cu	0,030	0,030	0,030	0,030	0,030
B	0,0090	0,0086	0,0081	0,0084	0,0081

In order to check the homogeneity of the chemical composition and in particular the distribution of Boron, analysis checks were carried out again at the end positions and the near centre area. Figure 22 is representing all the 4 investigated forgings so far. It can be seen, that the chemical composition is very homogenous from top to bottom as well as from edge to centre related to the ingot. The scatter of max 8ppm boron over the length / cross section of the ingot demonstrates an excellent boron distribution. The only exception to this is sometimes the boron content which seems to have lower values in the check analysis than in the melt analysis. This effect is currently under investigation within the Cost programme.
Two further shafts are currently under production and there is still an ongoing development process in respect of achieving a finer grain size for a better ultrasonic inspectability and an improvement of Charpy impact properties.
With respect to the fabrication of larger forgings, the intention of Boehler is more and more focussed on the use of remelted materials due to a better consolidation of the ingots compared with less segregations and a better homogeneity of the product. At the time test material in FB2 is produced by PESR melting process.

CONCLUSIONS

Boehler Edelstahl open die forge is an active partner for manufacturing components for gas and steam turbine applications in higher alloyed materials up to the newest generation of high chromium steels. Cost E and F are meanwhile well established and qualified and enjoy an increasing market worldwide with rising quantities. The development work within the Cost programm by contributing trial melts as well as full size trial rotors resulted in the fabrication of meanwhile more than 1000 forgings made of COST steel E and F. Steel FB2, containing boron, is now a most promising candidate for the next turbine generation. During the last year Boehler has started with the first production components ranging from 860mm in diameter up to 1090mm and length dimensions from 1300 up to 2700mm with delivery weights from 7 to 9,2 to.

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Abstract

Esperienze nella fabbricazione di forgiati per applicazioni nel campo della generazione di energia

Parole chiave:
acciaio, forgiatura, processi, materiali per l’energia

Disporre di fonti di energia sufficienti è un prerequisito che ogni paese deve considerare per mantenere un alto standard di vita. Questo fa si che sia necessario disporre di un adeguato numero di impianti di generazione di energia con tecnologie avanzate, in grado di accoppiare l’alta efficienza con un ridotto impatto ambientale. Quindi una sfida rivolta non solo ai costruttori di impiantistica per l’energia ma anche ai forgiatori che devono produrre componenti con materiali di composizione sempre più complessa, pertanto richiedenti passaggi produttivi a loro volta più critici.
Questo lavoro riporta esperienze di fabbricazione di forgiati per turbine a gas e a vapore, che devono possedere proprietà meccaniche e difettologiche focalizzate sui materiali più innovativi, ad alta resistenza alle sollecitazioni termiche, come la classe di acciai 9 –12 % Cr sviluppati nell’ambito del Programma Europeo COST.