Characterisation of AE961W Material Using NDT Methods—A Case Study

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ABSTRACT

AE961W martensitic steel material is heavily used for the applications of expendable gas turbine engine development. As a mandatory it is needs to be characterised for its quality for the critical applications. Metrology and NDT methods have been used for its characterisation in the current study. Samples have been prepared with necessary metrological characteristics and are subjected to various heat treatment conditions. The velocity (longitudinal and shear) and magnetism measurements are carried out to assess the effect the heat treatment conditions on the velocity values.

Keywords: Material Chracterisation, ultrasonic, surface roughness, heat treatment

Introduction

Gas turbine materials are expected to perform in varying environmental conditions and are likely to be subjected to failure mechanisms. AE961W is one such material and a steel alloy. It is basically martensitic steel which has properties suitable for the gas turbine applications. GTRE is using this material for the development of a Small Gas Turbine Engine in which this material has an important role for becoming the prime material for shafts, compressor stator and rotor blades, casings etc. The alloy has a good hardenability and due to martensitic structure has high strength, hardness and wear resistance.

Material Characterization consists of evaluation of elastic behaviour, microstructure, mechanical properties etc. NDT methods can be used to characterize properties of gas turbine materials to evaluate rate of degradation and residual life estimation.

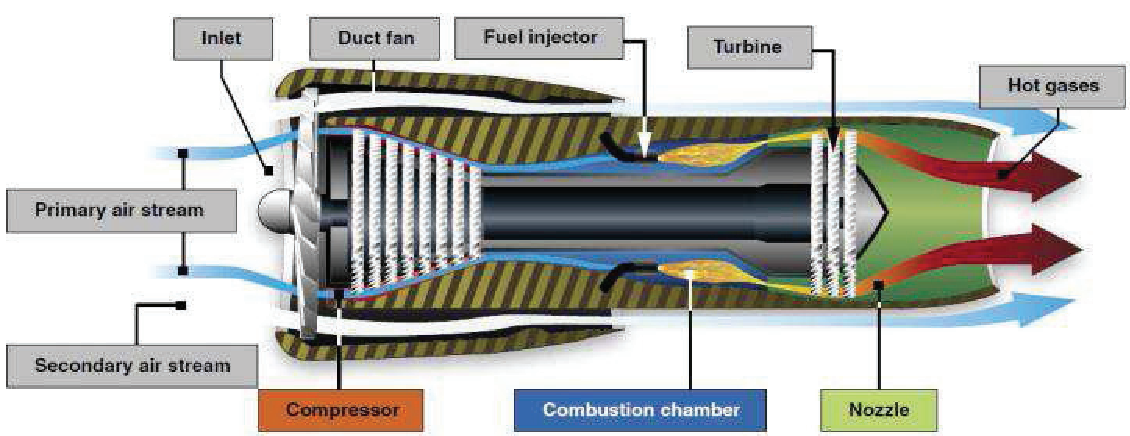

Fig1: Turbofan engine (*courtesy FAA pilot handbook*)

The standard heat treatment for AE961W is 1010^0C/OQ/+560-580^0C/AC or 1010^0C/OQ/+660-680^0C/AC. The ageing treatment of the material usually increases the hardness and strength. After normal ageing treatment further soaking was carried out increasing the time period. Subsequently, ultrasonic velocity measurements are tried on the samples to see the effect of heat treatment soaking times on the velocity values. The chemical composition of the alloy is given in the table1:

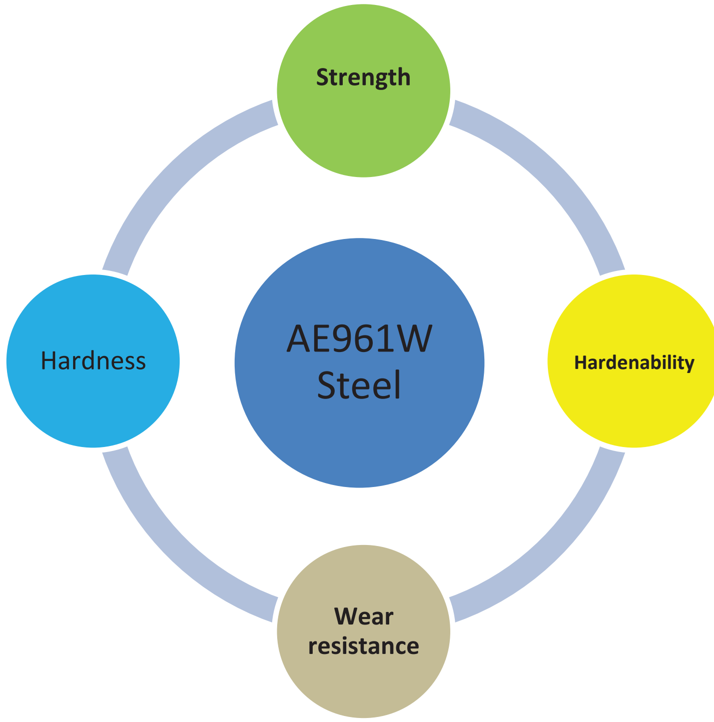

Fig 2: Main properties of AE961W

TABLE 1: Chemical Composition of AE961W

Element		C	Si	Mn	Cr	Ni	S	P	Cu	W	Mo	V	Fe
Wt %	Min	0.1	0.03	0.31	10.93	1.59	0.0007	0.16	0.046	1.73	0.39	0.19	Bal
	Max	0.14	0.43	0.49	11.46	1.85	0.007	0.02	0.082	1.84	0.44	0.27	

The current study is to see the effect of various soaking times on the behavior of the material by measurement of ultrasonic velocities and various other parameters. The experimental studies are carried out with help of specimens of specific size and roughness values.

Characterization using NDT methods

For carrying out the characterization of the AE961W, samples of size 80X30 mm are extracted from the forged bar. The sample designation, size, roughness and geometrical parameters are given in the table2.

Table 2: Sample details

Sample Design.	Diameter (mm)	Thickness (mm)	Surface Finish (Ra in microns)		Flatness		Parallelism (A w.r.t. B)
			A	B	A	B	
AE-1-1	80.124-80.127	30.12-30.14	0.861	0.385	0.013	0.002	0.019
AE-1-2	80.108-80.113	30.12-30.14	0.936	0.146	0.002	0.009	0.012
AE-1-3	80.074-80.081	30.14-30.15	1.582	0.325	0.011	0.008	0.017
AE-2-1	80.138-80.144	30.14-30.16	0.692	0.502	0.013	0.004	0.02
AE-2-2	80.096-80.107	30.17-30.18	0.314	0.88	0.009	0.013	0.023
AE-2-3	80.035-80.045	30.16-30.17	0.803	0.344	0.008	0.003	0.014
AE-3-1	79.880-79.886	30.14-30.16	0.205	0.181	0.009	0.014	0.016
AE-3-2	79.889-79.891	30.13-30.14	0.653	0.733	0.001	0.012	0.043
AE-3-3	80.087-80.079	30.16-30.18	0.506	0.129	0.001	0.006	0.008
AE-4-1	79.830-79.889	30.11-30.13	0.564	0.869	0.006	0.002	0.012
AE-4-2	79.892-79.900	30.14-30.16	0.669	0.856	0.006	0.01	0.01
AE-4-3	80.110-80.119	30.13-3014	0.432	0.429	0.004	0.01	0.01
AE-5-1	80.160-80.161	30.13-30.14	0.833	0.886	0.006	0.008	0.032
AE-5-2	80.136-80.127	30.17-30.19	0.917	0.713	0.02	0.015	0.025
AE-5-3	80.235-80.200	30.19-30.22	0.688	0.742	0.008	0.009	0.017
AE-6-1	80.973-80.976	30.29-30.31	1.007	0.848	0.007	0.008	0.04
AE-6-2	80.978-80.986	30.28-30.29	0.75	0.87	0.016	0.006	0.012
AE-6-3	80.914-80.917	30.30-30.31	0.591	0.701	0.001	0.004	0.007
AE-7-1	80.962-80.963	30.29-30.30	0.526	0.835	0.01	0.011	0.021
AE-7-2	80.986-81.018	30.26-30.27	0.415	0.689	0.003	0.007	0.052
AE-7-3	80.915-80.918	30.29-30.30	0.565	0.997	0.004	0.007	0.01
AE-8-1	81.001-81.005	30.26-30.29	0.895	0.769	0.005	0.015	0.034
AE-8-2	80.997-81.003	30.27-30.30	0.902	0.829	0.003	0.014	0.032
AE-8-3	80.963-80.969	30.28-30.29	0.62	0.54	0.019	0.011	0.016

A total of twenty four specimens are manufactured from AE961W material. Dimensional and geometric feature measurements and surface roughness measurements are carried out. Heat treatment of the specimens is carried out as per the decided cycle for the material specimens. The pictures of the samples are shown in the figure1. The heat treatment followed is given as:

a) Preheating 300-400^{0}C for 15-30min in Air circulation furnace
b) Hardening 1010±50^{0}C for 15min/hr in vacuum furnace followed by GFQ

For other set of samples the heat treatment temperature is 1010±50^{0}C with varying soaking periods from 4 to 14 hours.

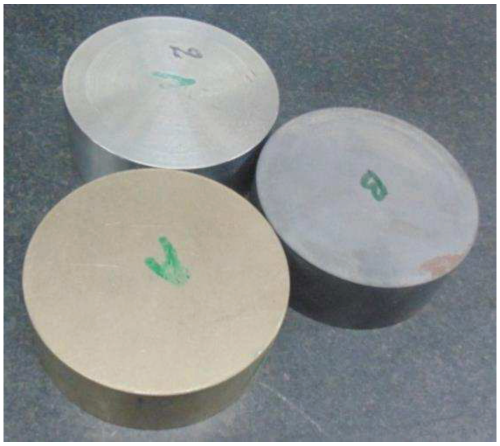

Fig.3: AE961W specimens

The methodology employed for the evaluation/characterisation of the AE961 W samples is explained in the table3. Ultrasonic testing for the velocity, attenuation measurement and the Rockwell testing for hardness measurement was carried out on all the samples.

Table 3: Characterisation methodology and parameters

Material	Heat Treatment Condition	Methodology	Parameters
AE961W	ST, STA, STA+4hrs, STA+6hrs, STA+8hrs, STA+10hrs, STA+12hrs, STA+14hrs	Ultrasonic Testing, Rockwell hardness testing	Longitudinal velocity, Attenuation, Rockwell hardness

Ultrasonic velocity measurement was carried out on USN-60 model and hardness measurement was carried out on Ultrasonic equipment. The details of the equipments used for the measurements are given in the table 4 and 5.

Fig4: Ultrasonic velocity measurement on specimen with USN60 equipment

Table 4: Ultrasonic shear velocity, hardness and attenuation in AE961W samples in heat treated condition with variable soaking periods

Sample Design.	**Heat treatment**	**Shear Velocity, m/s**	**Hardness, HRB (Mean)**	**dB= 20logH2/H1**	**dB/mm**
AE-1-1	1010±5^{0}C for 15min/ hr in vacuum furnace followed by GFQ (ST)	3268	55.70	10.64	0.177
AE-1-2		3235	64.30	10.64	0.177
AE-1-3		3288	59.84	11.09	0.184
AE-2-1	STA	3209	74.40	11.41	0.190
AE-2-2		3176	70.30	10.64	0.177
AE-2-3		3189	69.75	10.94	0.182
AE-3-1	STA/4hours	3201	72.75	11.09	0.184
AE-3-2		3204	64.20	11.41	0.190
AE-3-3		3174	79.25	10.94	0.182
AE-4-1	STA/6hours	3200	77.10	10.94	0.182
AE-4-2		3194	75.20	11.09	0.184
AE-4-3		3229	76.30	10.64	0.177
AE-5-1	STA/8hours	3210	67.15	12.04	0.200
AE-5-2		3233	68.05	11.09	0.184
AE-5-3		3193	64.05	11.09	0.184
AE-6-1	STA/10hours	3209	68.50	10.34	0.172
AE-6-2		3197	79.45	10.64	0.177
AE-6-3		3201	74.05	11.25	0.187
AE-7-1	STA/12hours	3173	74.95	11.25	0.187
AE-7-2		3198	67.00	11.09	0.184
AE-7-3		3218	70.75	11.09	0.184
AE-8-1	STA/14hours	3193	70.30	11.49	0.191
AE-8-2		3192	71.10	11.41	0.190
AE-8-3		3216	58.65	09.69	0.161

RESULTS, DISCUSSION & WAY FORWARD

The results of the study revealed the an appreciable change in the shear velocity, hardness and attenuation values with respect to the various heat treatments carried out on the test specimens of AE961W material. The relation generated for the specimens w.r.t. respective hardness value is given in the Fig.5.

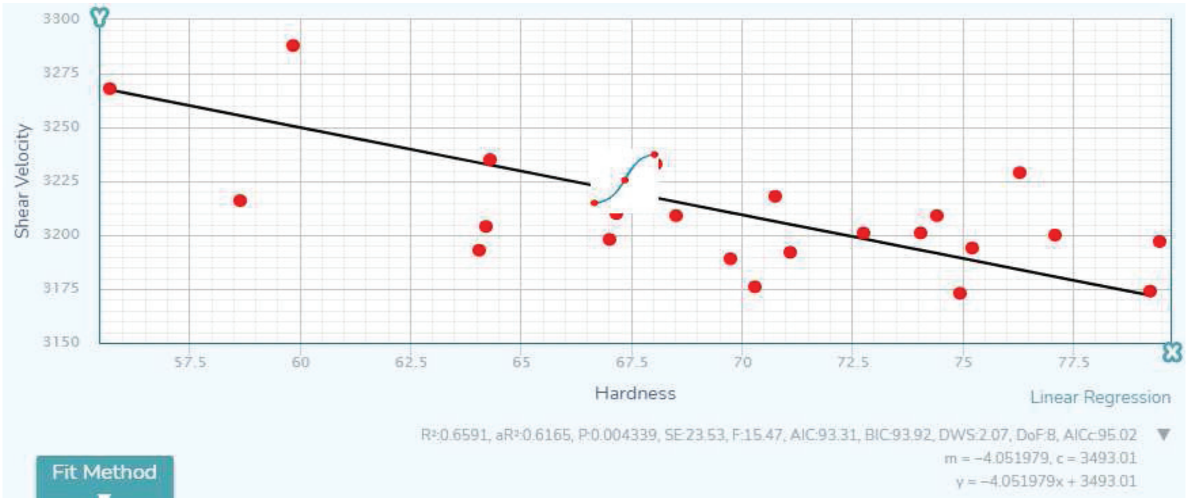

Fig5: Ultrasonic Shear Velocity vs Hardness for AE961W

The fitting method is a linear regression with a regression coefficient of 0.66 giving a positive relation between hardness and shear velocity at various heat treating stages.

The methodology can be adopted for the relation for the practical engines components like shafts, casings etc. going through various heating conditions during the testing at test levels.

Future work will be evaluated as residual magnetism measurements w.r.t. changes due to heat treatment and also correlating the ultrasonic material properties with the actually affected parts

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