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Design and analysis of Ti6AL4V Titanium specimens for enhancing fatigue life performance using ultrasonic impact treatment

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Abstract___ Stresses are the prime source for the fatigue life diminution. In order to increase the fatigue life of the welded module, the residual stresses has to be minimized and this can be primed by choosing appropriate material in fabrication of the part and by adopting suitable welding process. There is another possibility to reduce the induced residual stress and thereby increasing the component life under fatigue loading, is by the application of post weld treatments. In the class of mechanical post weld treatments, Ultrasonic Impact Treatment is relatively new post weld treatment method. Ultrasonic Impact Treatment (UIT) imparts the energy generated from high frequency impulses into treated surface through specially designed strikers leading to the plastic deformation of surface layers. The technique is also recommended due to its high process stability and low operating costs. Modest initial loads are used in UIT to produce deep penetration work hardening of minor surface roughness. This technique accordingly opens up applications that are impossible to achieve using conventional work hardening technique.

Key words - Ultrasonic Impact Treatment (UIT), welding, fatigue, residual stress.

I. Introduction

Aerospace industry concentrated on reducing the residual stress level in aero gas dynamic engines. From the perspective of aero gas turbine engines there are two best possibilities for reducing the stress and to increase the component life one is by choosing the appropriate material which can resist the residual stresses and other way is the post weld treatments. There is a significant study in the materials and their properties. Concerning that it is professed to opt Titanium alloys over other materials.

Titanium Grade 5 (Ti6Al-4V) is the most universally used alloy. Ti6Al4V is significantly stronger than commercially pure titanium while still retaining the same stiffness and thermal properties (excluding thermal conductivity). Titanium Grade 5 broadly used in Aerospace, Medical, Marine and Chemical Processing. NIMONIC alloy 263 is generally available in the following forms:

Properties of Ti6A14V
Mechanical Properties:

Brinell hardness	334	
Hardness, Rockwell C	36	
Tensile Strength, Ultimate	950	MPa
Tensile Strength, Yield	880	MPa
Elongation at Break	14 %	
Compressive yield strength	970 MPa	
Poisson's Ratio	0.342	
Fatigue Strength	510 MPa	

Physical properties:

Thermal Conductivity	6.7 Kj/kgok
Melting Point	1604 – 1660

General failures ensues in aerospace components

The following are the general failures occurs in aerospace component

- Low cycle fatigue
- High cycle fatigue
- Erosion
- Thermo mechanical fatigue
- Fretting and wear
- Creep
- Over stress

The component fatigue life is not only depends upon the choice of the material and the magnitude of the mean and cyclic stresses. These general failures can be overcome by plummeting residual stress caused due to fatigue loading conditions.

Residual stress

Residual stresses are stresses instigated due to dissenting internal enduring strains. These stresses are generated or modified at any stage in the component cycle from initial material production to final disposal. Residual stresses are inside the component or locked into a component or assembly of parts.

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These residual stresses generally originate in welded minutiae and are created by welding. In welding, rapid thermal expansion and contraction created along the much localized area is a prime source of residual stresses. Residual stresses moderate the performance of the structural associate and catastrophe the manufactured constituents.

Although there are different local post weld treatments to reduce the residual stress and to surge the life of the existing structure. In this experimental work it is opted to use ultrasonic impact treatment to reduce the residual stress and to escalate the fatigue life.

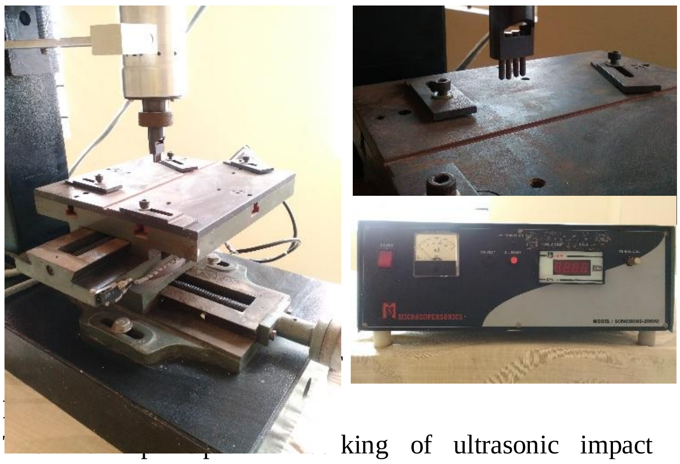
II. Material and Methodology

Ultrasonic Impact Treatment

The Ultrasonic Impact Treatment is the new and progressive technique in post weld treatment methods. UIT device was originally invented by Dr EfimStatnikov. Ultrasonic Impact Treatment method involving a deformation treatment of the weld toe by a mechanical trouncing at a frequency of 20 KHz which results in plastic deformation of the surface and reducing stress concentration by smoothening of the weld profile.

Testing equipment:

Ultrasonic impact device entails of ultrasonic generator and ultrasonic tool. The ultrasonic tool composed of ultrasonic transducer, booster and impacting needle.



king of ultrasonic impact equipment is applying of electro sonic waves to the component these ultrasonic waves are generated from electromagnetic transducer. The resonator is caused to vibrate along with this transducer and the energy generate from these high frequency impulses is divulged to the treated surface through the pins which can move freely on the surface.

Test rig

The equipment consists of 12”x 20”size Cast iron X&Y table mounted on base. Impact gun mounted working table with motorized X movement

Model	: Sonobond 20 Khz
Generator	: 20 Khz ±0.5Khz
Power supply	: 220V, 50Hz, 5A
Max Power	: 500Watts,
Output power	: 10-100% variable by dimmer.
Gun	: PZT Pistol type with cooling fan.
Pins Collette (Steel)	: Diameter 3mm x 4pin-1 no
Diameter	: 4mm x 3pin-1 no, diameter 5mm x1pin-1 no,

Figure 2: UIT device with fixture for automatic movement of the Impactor

Experimental studies

CAD modeling

The I section has been cutted through EDM technique as per ASTM Standard. The I section has designed in CATIA V5 R23.The CAD model is shown in figure 3.

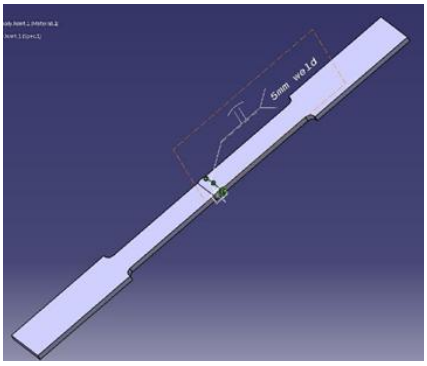


Figure 3: I SECTION CAD MODEL

Test procedure

To study the effect of Ultrasonic Impact Treatment on the welded material, the treatment has been done by fixing the samples on the table and the Impactor in the holder on the fixture. Initially to know the effectiveness of the treatment some of the samples are treated.

Scrutinizing specimen

Treatment has been done on the parent metal and also on welded samples of Ti 64 supplied by using 3mm diameter multiple indenter and 5mm diameter single pin indenter with different speed of the Impactor. The speed of the impactor maintained is 3mm/s, 6mm/s and 9mm/s. The following figure show untreated samples of parent metal and welded components of Ti 64.

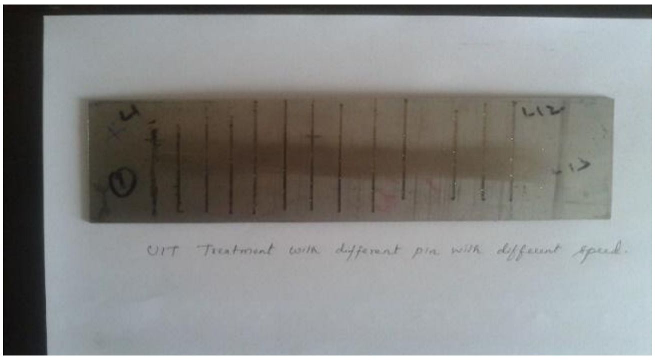


Figure 5: Samples of Parent metal after treatment by 3mm multiple indenter

The UIT effect depends on various parameters. To know the effect several researchers conducted the study by considering the parameters like indenter size, load of the indenter, and feed of the impact. In this work also we have considered few parameters for study. The equipment has the facility for conducting the treatment by varying the parameters, such as Indenter size and feed. The different feed of the indenter can be obtained by varying the velocity of the table.

The parameters used for the UIT are

- Indenter Size
  - 3mm diameter Multi Pin
  - 5mm diameter Single Pin
- Indenter Feed (Speed of the table)
  - 3 mm/sec
  - 6 mm/sec
  - 9 mm/sec.

For optimization of these parameters treatment has been done on 316L Steel samples. The 316L stainless steel which is more resistant to general corrosion.

The samples of parent and welded components with the dimension of 185X200 X 1.1mm is as shown below in the figure 16 where the weld sample is made of TIG welding process.


ded


Ultrasonic Impact treatment is done on surface of the parent samples by varying the parameters to achieve the optimum consequences.

Figure 7: UIT Treatment with different pin with different speed

The above figure illustrates the UIT treated specimen with the various parameters for the optimization of the UIT. The notation e, f, g, h in the figure as illustrated above consists of set of indentation where the pins are arranged to impact in parallel and in rest of all the notation the pins are arranged to impact in series

III. Results and Discussions

Specimen	Load at yield (Kgf)	Stress at yield (Mpa)	Peak load (Kgf)	Peak stress (Kgf)	% Elongation
Untreated 1	1488	973	1609	1052	25.67
Untreated 2	1446	945	1578	1032	20.27
Treated 1	1233	806	1685	1101	10.44
Treated 2	1432	936	1702	1112	2.79

TABLE 1: Summary of treatment on Parent Material

From the above table it is observed that during

NOTA TION	INDENTER SIZE (mm)	INDEN TER FEED mm/sec	FREQUENCY(Hz)	
			Initial	Operating
a	3mm multipins in series	9	19924	19820
b	3mm multipins in series	9	19920	19830
c	3mm multipins in series	6	19913	19818
d	3mm multipins in series	3	19911	19819
e	3mm multipins parallel	9	19918	19820
f	**3mm multipins parallel**	**9**	**19918**	**19823**
g	3mm multipins parallel	6	19906	19825
h	3mm multipins parallel	3	19922	19830
i	5mm single pin	9	19928	19840
j	5mm single pin	6	20022	19850
k	5mm single pin	3	19919	19837

experimentation the operating frequency slightly varies from the standard frequency 20000Hz, which is due to the gap between the indenters and Impactor needle.

Due to impacting, the surface layer becomes harden. Hence Rockwell hardness test (RHT) has been conducted on impacted area with the specification of 1.585mm diameter ball indenter with 'B' scale and load of 187.5 Kgf.

From the above results it is observed that after the UIT the hardness has been improved. For sample no c (3mm diameter single pin in series with speed 3mm/sec) gives the maximum hardness compare to other parameters.

From this work we can conclude that impact treatment using 3mm diameter multi pin with indenter feed rate of 9mm/sec is effective.

The treated sample breaks at treated surface, but untreated sample failed at other location

No. Of pins	Velocity	Location	Raw data		Average hardness hv5
3 pins	3 m/s	L – 1	306	310	308
	6 m/s	L – 2	303	313	308
	9 m/s	L – 3	310	317	314
	12 m/s	L – 4	317	310	314
4 pins	3 m/s	L – 5	306	313	310
	6 m/s	L – 6	332	317	325
	9 m/s	L – 7	329	325	327
	12 m/s	L – 8	313	306	310
Single pin	3 m/s	L – 9	330	325	328
	6 m/s	L – 10	299	303	301
	9 m/s	L – 11	300	306	308
	12 m/s	L – 12	298	308	301
		L – 13(base)	292	296	294

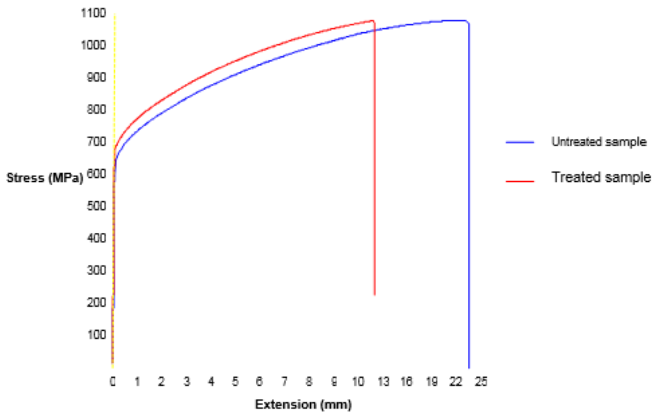


TABLE 2: Hardness Test Results of UIT treated Parent Material

The graph shows the tensile test results of Ti6Al4V sample of 1.2 mm thickness

It is observed from the above graph the performance of the treated and untreated samples is almost similar up to yield point after that treated samples show the better performance than the untreated samples. The treated samples fail with minimum extension than extension of untreated samples. The maximum load carrying capacity is almost same for both treated and untreated samples, but treated samples requires slightly more load to fail while compared to untreated samples, which indicates residual stresses affect the strength of the material.

The fatigue test results are obtained at every 500 cycle for different stress range from 600-60 MPa to 1100-110GPa with a stress ratio of R=0.1.The stress ranges followed was 600-60, 800-80, 900-90, 1000-100 and 1100-110 Mpa.

The test results shows all the untreated samples are failed within 150 cycles for maximum stress range 1100-110 GPa. But treated specimens are not failed at higher stress range and up to 500cycles except one specimen. This indicates treated specimens shows better fatigue life than untreated specimens. From this we can conclude that ultrasonic impact treatment enhance the fatigue life of the TIG welded components.

IV. Conclusion

The overall objective of the work presented in this report was to gain and apply an understanding of the ultrasonic impact effects on residual stresses in welded components. The ultrasonic treatment has been done on the Titanium Grade-5 to know the feasibility of the technique. The device is designed for a constant frequency of 20 kHz. Treatment is done on the Ti-64-TIG welded samples and results are comparable. The following conclusions are drawn from this work.

- Ultrasonic impact treatment is effective method for relieving residual stresses in welded joints compared to other methods followed earlier.
- The treatment enhances the fatigue life of the titanium alloys.
- The effectiveness of the treatment depends on several parameters like impactor diameter, impactor feed and frequency of the impact.
- In this work the effectiveness of this technology is not showing substantial improvement as compared to the results quoted by many researchers as discussed in the literature survey. This may be due to low impact on the Ti-64 samples by impact pins made of steel or thermal stresses induced in the weld having lesser magnitude due to thin section.
- The equipment used for treatment is compact and light weight and easy to handle manually, hence this technique is more convenient than other conventional techniques.

References:

i. Haagensen, P.J., Statnikov, E.S. and Louis Lopez-Martinez, Introductory Fatigue Tests on Welded Joints in High Strength Steel and Aluminium Improved by Various Methods Including Ultrasonic Impact Treatment (UIT), IIW, Doc. XIII-1748-98

ii. Pasta S, and Reynolds A. P., (2008) Residual stress effects on fatigue crack growth in a Ti-6Al-4V friction stir weld, Fatigue and Fracture of Engineering Materials and Structures, 31 (7), pp. 569-580.

iii. Lihavainen, V.M., G. Marquis, E.S. Statnikov, Fatigue Strength of a Longitudinal Attachment Improved by Ultrasonic Impact Treatment, IIW Doc. XIII-1990-03.

iv. Nalla, R.K., Altenberger, I., Noster, U., Liu, G.Y., Scholtes, B. and Ritchie, R.O. (2003). On the influence of mechanical surface treatments—deep rolling and laser shock peening—on the fatigue behavior of TI-6AL-4V at ambient and elevated temperatures. *Material Science Engineering, A355,* 216–230.

v. Statnikov, E.S., (2006), Ultrasonic Impact Methods for Treatment of Welded Structures, US Patent 6,338, 765

vi. Jian Liu, (2002) Handbook on Residual Stress, Society of Experimental Mechanics, Vol. 1, 14-17.