ASAT

MILITARY TECHNICAL COLLEGE

CAIRO - EGYPT

ON FURTHER USES OF SHOT PEENING IN THE AIRCRAFT REPAIR AND OVERHAUL FIELD

M.ABD-EL SALAM* AND M.GABRA**

ABSTRACT

It is more than likely that a fair percentage of aircraft components are used within an environment that were not designed for it at the first place, consequently some defects may appear long before the expiry of the time between overhauls. Aircraft users may develop special repair and maintenance techniques suitable for their own particular environment. Reliability, effectiveness and airworthiness should not be affected by the adopted repair techniques. A successful exercise in this field may lead to important design aspects for the designers to bear in mind for this particular environment. Another important issue in the A/C repair/overhaul business is the compulsory use of alternatives instead of the original item/material either because of availability problems or economical reasons. When the technical specifications of an alternative does not meet the genuine item/material specification endeavors should not be spared to promote the reliability of the alternative bearing in mind all the side effects of the techniques used in the course of doing that.

Along the lines of case No. 1 this paper will discuss the suceptibility to fretting corrosion of the oscillating races of helicopter hub bearings operating in a reactive environment; and how shot peening was used to decrease the suceptibility to fretting corrosion (false brinelling).

For case No. 2 this paper will discuss the use of special shot peening technique to promote the bonding strength of the blade pockets to the helicopter blade spar when using an alternative bonding procedure and material.

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* Col.Eng., Head of Planning Dept. , Egyptian Airforces Main Workshops, Cairo - Egypt.

**Lecturer, Dept. of Aeronautical Engineering, Military Technical College, Cairo - Egypt.

INVESTIGATION AND ANALYSIS

Fault find procedure for case No. 1
More than 50 helicopter hubs were investigated when they were sent back to depot level for various reasons after different flying hours ranging from 100 hrs to 1000 hrs.
Oxidation of metal surfaces where parts are closely fitted was noticed specially in the feathering hinge subjected to angular oscillation under stress. Further surveys including non destructive inspection, micrometric measurements and spectrometric oil analysis procedures were carried out. Earlier corrosion took place on parts belonging to helicopters operating in the sea vicinity when compared with similar parts of helicopters working in land. In general corrosion started after 250 flying hours in the sea vicinity; after 500 hrs corrosion was serious and no permissible refurbishement was possible. The investigation results lead us to think that the damage developed at the contact area with the rolling element as the loaded bearing is subject to angular oscillation and vibration.
The lubricant was forced out of the contact area and was not replaced adequately because the angular displacement is small; that was evident due to hot running signs for a start. Metal to metal contact occured and the sliding motion caused submicroscopic particles to be sheared from high spots.
As the displaced particles were very small; immediate oxidation took place which account for the red rust assoicated with the fretting corrosion experienced. The oxides acted as a lapping compound and accelerated the metal removal which was evident by examining different oil samples after different flying hours by spectrometric oil analysis procedure and the micrometric checks. Some atmospheric contaminants were detected in some oil samples.

* CORRECTIVE ACTION AND REPAIR TECHNIQUE ADOPTED

The corrective action was done to components which were lightly corroded after 250 hrs of service.
Lightly corroded races were treated with phosphoric acid base solution for 30 seconds then rinsed and immersed in dewatering oil then wiped with lint free cloth.

The component was shot peened by fine beeds for 15 minutes. Shot peening technique was selected as a repair procedure because of its ability to provide three main objectives in one go that is.

- The elemination of different stress raisers such as bruses or scratches (specially at the fretted areas) without any metal removal.
- The creation of beneficial residual compressive stress in the surface layer of the peened component which delays the stress corrosion cracking and diminshes the suceptibility of the material to fretting corrosion.
- The improvement of the oil retention properties of the plain bearings, as the small deuts on the bearing surface act as reservoirs which effectively retain lubricant when heavy loads are applied.

* RESULTS OF THE CORRECTIVE ACTION

Items that were treated at 250 operating hours were able to withstand after 1000 hours of corrosion free service where untreated items suffered fretting corrosion after an average of 250 flying hours.

Wear of the race ways was considerably reduced consequently traces of metal inclusions and oxides in the lubricating oil were stabilized after the debugging period which in this case was about 5 flying hours after the repair.

Oil discolouration phenomenon that characterised the operation of the closeliy fitted parts was much reduced indicating better lubrication qualities and cooler running.

TECHNICAL DISCUSSION OF CASE "1"

There is much that can be done to increase physically the fatigue strength of many parts made from ordinary structural materials. This fatigue strengthening does not require change in design or in material. The significance of the technique that we adopted has become clear through the introduction of relatively new concepts of fatigue phenomena by which new avenues of reasoning are opened. These new concepts are : Fatigue failures result from tension stresses not from compressive stresses, and any surface, no matter how smoothly finished is a stress raiser. The surface of repeatedly stressed specimens, no matter how perfectly they are finished, are much more vulnerable to fatigue than the deeper layers. It has long been appreciated that the vulnerability to fatigue increases as the surface roughness consists of sharp notches and more particularly if the notches are oriented at right angles to the principal stress. This extra surface hazard may be due to submicroscopic notch effects or to the fact that the surface is a discontinuity since the outer crystals are not supported on their outer faces.

The fatigue strength of the most carefully prepared specimen will be increased if a thin lager of the specimen is prestressed in compression [1] by a peening operation such as peen hammering; swaging, shot blasting or tumbling or by pressure operations by balls or rollers. A compressive stressed surface is effective in increasing the fatigue strength whether applied to highly finished specimens or to specimens having rough surfaces [2]. Fatigue failures in many machine parts are traceable to corrosion of several kinds or to other forms of surface damage that occur in service. The damaging effect of corrosion or bruising is prevented on the surfaces that are adequately protected by compressive pre-stress because the local tension stress can not become dangerously high until the pits or bruises have progressed sufficiently to penetrate the compressively stressed layer. This was forcefully demonstrated in fatigue tests of a machine part that failed alternately in a badly formed fillet or in the region of a clamp remote from the fillet where fretting corrosion occured. The durability of the part could not be increased by improving the fillet because this would merely transfer all failures to the fretted area at about the same durability. After peening, however, the fatigue durability was found to have increased several hundred percent and large additional gains were then possible by improving the form of the fillet without failure in the corroded area. The peening did not prevent corrosion but did prevent the ill effect of corrosion in promoting fatigue.

We used shot peening to get rid of stress raisers created by fretting corrosion for the above mentioned reasons besides we think that if machine polishing is done by the use of abraisve paper or cloth wheels; or abrasive covered felt wheels; sufficient heat is often generated to induce serious surface tension stresses and thus promote instead of prevent fatigue failures. The improved lubrication properties from our point of view is due to better oil retention properties that plain bearings gain by shot peening.

This principle has been applied to wrist pins; crank shafts thrust bearings, etc. and has proven eminently satisfactory. The reaction of the environment with the stressed metal may so advance the development of cracks and the time to failure is much reduced. It was evident in our case No. 1 that fretting corrosion with the associated stress raisers early appeared in component fitted on helicopter operating in the sea vicinity associated with atmospheric contaminants due to an active industerial community without adequate antipolution regulations.

Among the factors causing fatigue failure to be exaggerated are atmospheric contaminants such as ammonia or sulphur dioxide and chlorides in sea waters [3] Not only the susceptible materials such as carbon steel but also corrosion resistant alloys such as some cupro nickel, chromote steels and alluminium alloys are subject to corrosion fatigue at quite low stress levels.

The essential features of corrosion fatigue are the coincidence of cyclic stressing and the presence of a reactive environment. Under these conditions the effect of cyclic loading in creating cracks is accelerated and propagated by increased chemical reactivity [4]. It is noted that when fatigue occure prior to exposure to corrosion it is not as destructive as when they both occur simultaneously.

There are many preventative techniques to control corrosion fatigue such as hardening the surface of the alloy by conventional case hardening techniques; Introducing residual compressive stresses by nitriding; electroplating of zinc or pure alluminium and the use of organic coatings.

We used shot peening to impart residual compressive stresses on the surface layer to promote corrosion fatigue resistence besides the two previously mentioned merits of shot peening that is improving lubrication properties and the elemination of crack raisers initiated due to fretting corrosion.

The effect of shot peening on short crack propagation is still under investigations but we think that the residual compressive stresses imposed on the surface layer by shot peening has a benefitial action on the crack propagation if not due to plasticity effect it will be due to offsetting the tensile stresses on the surface.

Result have been presented indicating that in different unpeened materials short cracks may propagate faster ; at the same rate ; or more slowly than longer cracks [5-7]

The relationship $\Delta K = \Delta\sigma\sqrt{\pi . a} . f(a/w)$ [- where $\Delta\sigma$ is the stress amplitude and "a" is the crack length; ΔK is the stress intensity amplitude; f (a/w) is a geometrical function -] between the stress intensity amplitude and crack length indicates that at threshold value ΔK_o the critical crack length at which fatigue crack propagation can occur is inversely related to the applied stress amplitude. At smaller crack or defect size the sustainable fatigue stress increases, untill the value of fatigue limit for equivalent smooth uncracked specimen (σ_o) is attained. At this point the above relationship will be $\Delta K_o = \Delta\sigma_o\sqrt{\pi a_c}$. f(a/w) and is valid for both short and long cracks and the important feature for peened specimens is that peening will affect the length to depth ratio affecting the geometrical function f(a/w) specially in the presence of surface inclusions. Further investigations in this area concerning the peening effect both on crack initiation and crack growth is underway.

CASE NO. 2

Technical approach

Replacement of helicopter blade bockets is a sencetive operation as it deals with a highly stressed item " The blade spar " and a lot of cutting and cleaning operations are encountered and no mater how strict safety precautions are some dents; bruises and sometimes scratches may result in.

Moreover; the bonding of the new pocket should satisfy at least a minimum of an acceptable bonding strength value.

As for dents, bruises and scratches they are hazardeous stress raisers and they can not be ignored no matter how small they are; any polishing or mechanical cleaning action should not be done in a chord wise direction as it may disturb the surface fibers in a perpendicular direction to the bending action of the spar. That will make it difficult to eleminate stress raisers specially at the corners. A certain minimum of the wall thickness of the spar should not be overlooked and any repair procedure implying metal removal should be avoided.

For all the preceding factors we adopted shot peening technique to eleminate stress raisers on the spar without metal removal and to prepare a better surface for bonding as it will provide a rouhened with no harm surface securing better gripping for the adhesive.

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TECHNIQUE USED AND TESTING PROCEDURE

A shot peening shroud was provided, when mounted on removed pocket area it will be equally spaced around it.

The bonding area was shot peened using 180 - 220 alumina grit at a pressure of 4.2 to 5.6 Kg fm/cm² until a matt grey surface has been achieved that is approximately 10 minutes.

Safety measures were taken to prevent the grit to enter the adjacent pockets.

The peened area was treated by Alocrom 1200 then primed then the pocket was bonded using bonding jig with heating elements; the temperature of curing was chosen to suit the film adhesive choosen in such a way that the spar is not affected as shown . Fig 4 consequently the merit of shot peening action on fatigue strength was maintained.

For optimum results the preparation, pre-treatment and bonding operations must take place in a dust free area at a temperature of 20 - 30^{o}C with relative humidity not exceeding 60 %.

After bonding is finished a peel test was performed using special clamp and spring balance; the peeled back portion of the skin was pulled and the fulctuating readings were registered.

The procedure was repeated on the portion of skin on the other surface of the blade. Force needed to peel back the bonded skin from peened samples were found to be of an average of > 20 Kgf where the unpeened samples recorded an average of < 13 Kgf with all the pretreatment and bonding operation kept the same.

So we think that sparsely peening the surface to be bonded enhanced the bonding strength of the blade pocket.

GENERAL DISCUSSION AND CONCLUSIONS

Shot peening is a cold working method accomplished by hitting the surface of a metal part with round metalic shots thrown at a relatively high velocity.

Each shot acts as a tiny pein hammer, making a small dent in the surface of the metal and stretching the surface radially as it hits. The impact of the shot causes a plastic flow of the surface fibers extending to a depth varying from 0,125 to 0,750 [mm] are rather common but values either higher or lower than this range can be practical.

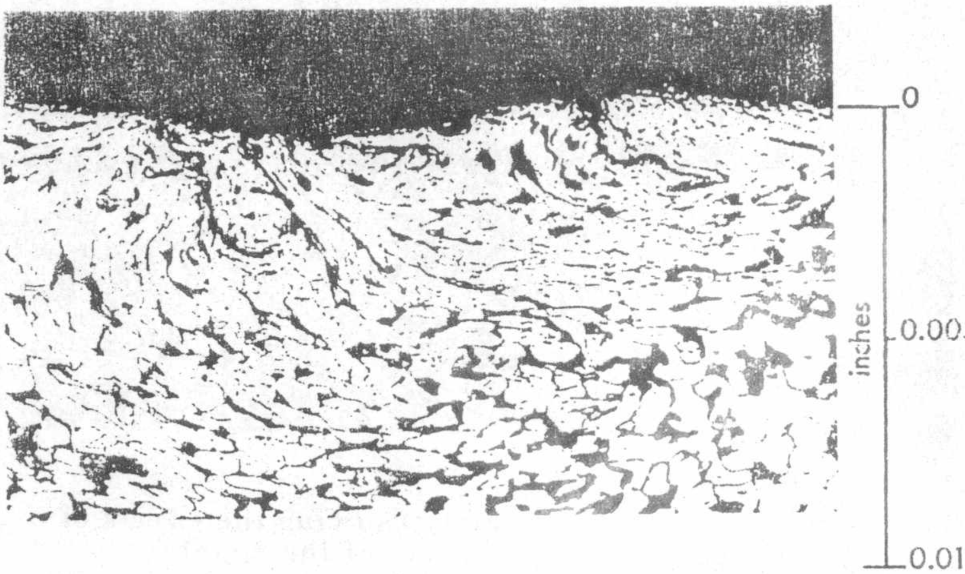
The fibers underneath the top layer however are not stretched to their yield point and therefore retain their elasticity.

The underfibers are of course adhered to the stretched surface layer and after the peening action the inner fibers force the outer fibers to return to a shorter length than that at which the stretched fibers would tend to remain in equilibrium which results in that the surface fibers are in residual compression while the inner fibers are in tension micrograph of longitudinal section of shot peened steel is shown in fig. (1). For aluminium alloy is shown in Fig.2

The change of shape and orientation of crystalline grains is not the only change caused by shot peening. As the individual pieces of shot strike the metal, each one sets up localized stress longitudinal; transverse and prependicular compression at the surface and at a slight distance below it. After the shot bounces off some residual stress remains in and near the surface - a longitudinal compressive stress and a vertical compressive stress a little below the surface. The net result of this state of three dimensional stress tends to offset any longitudianl tensile stress applied by a load or a bending moment. Then; since tensile stress of a given intensity has more tendency to cause the start of a fatigue crack than a compressive stress of the same intensity this state of residual stress set up by shot peening in general increases the fatigue life of a shot peened piece. A curvature caused by shot peening,Fig.3, Shot peening does produce a great many shallow "dents" in the surface metal, dents with a smooth spherical surface. Moreover these dents are spaced very close together.

The stress intensifying influence of a very shallow dent is rather small and the stress intensifying influence of a number of "stress raisers" of any type - dent, notch, hole, fillet - spaced close together is less than that of a single stress raiser [8]

6 Closely spaced stress raisers seems to some extent to share the intensified stress among themselves instead of leaving the whole intensification of stress to be carried by one stress raiser.



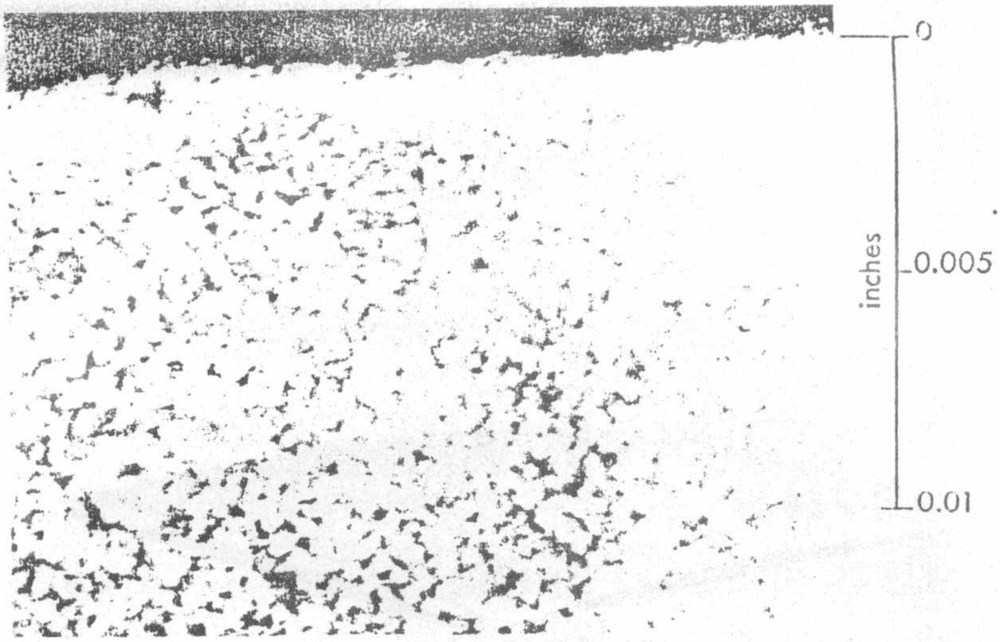


Fig. 1

Micrographs of Longitudinal Sections of Shot-Peened Steel

Upper—S.A.E. 1020 Steel, Shot-Peened

Lower—S.A.E. 1010 Steel. Carburized and then Shot-Peened.

Magnification 200 times.

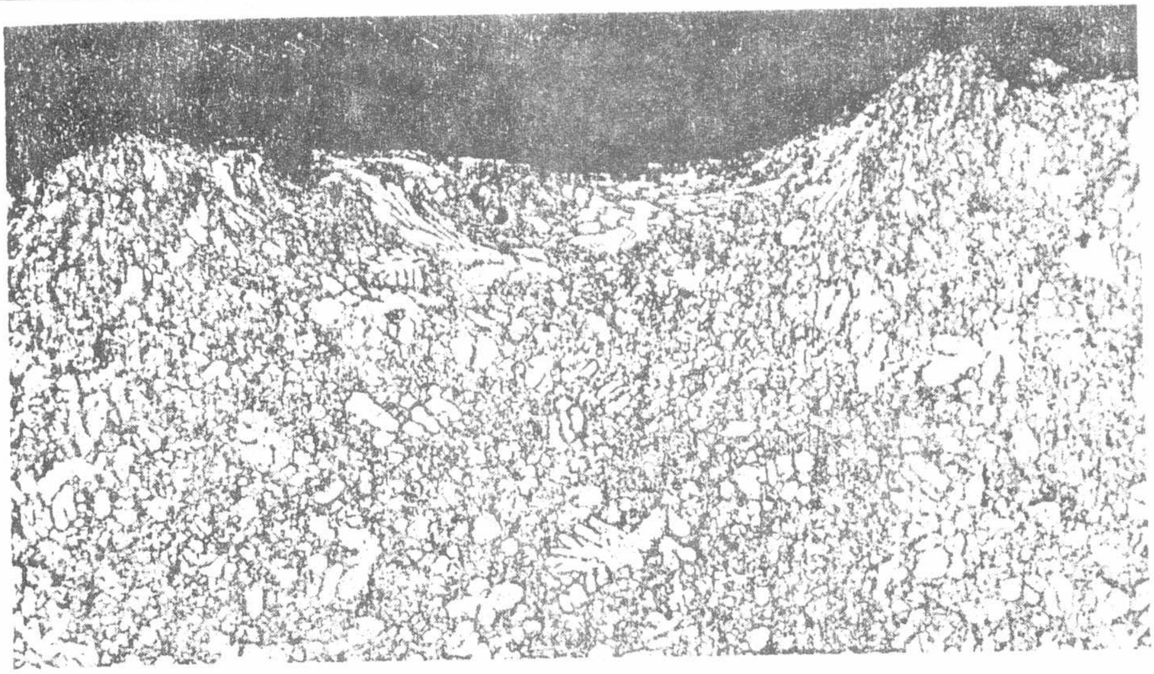


Fig. 2

Photomicrograph of an aluminum alloy showing the effects of shot peening on the surface layers of the metal.

Magnification 100 Times.

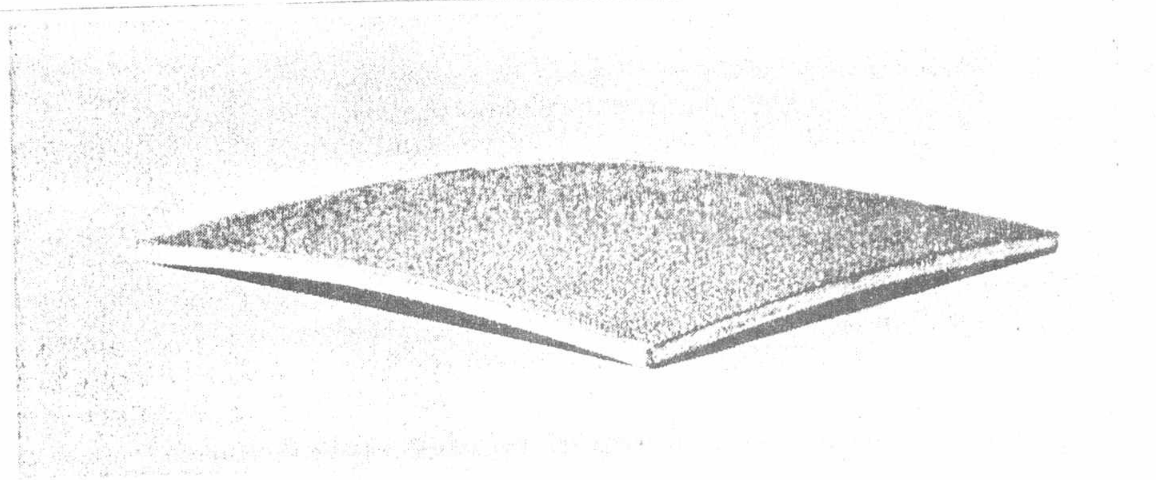


Fig. 3

S. A. E. 1020 Steel 4 x 4 x 1/8 Inch Shot-Peened on One Side.

The double curvature of the piece after shot peening indicates residual compressive stresses in two directions at right angles. Probably there are also vertical residual stresses in the piece.

TEMPERATURE CONTROL DURING BONDING OPERATION

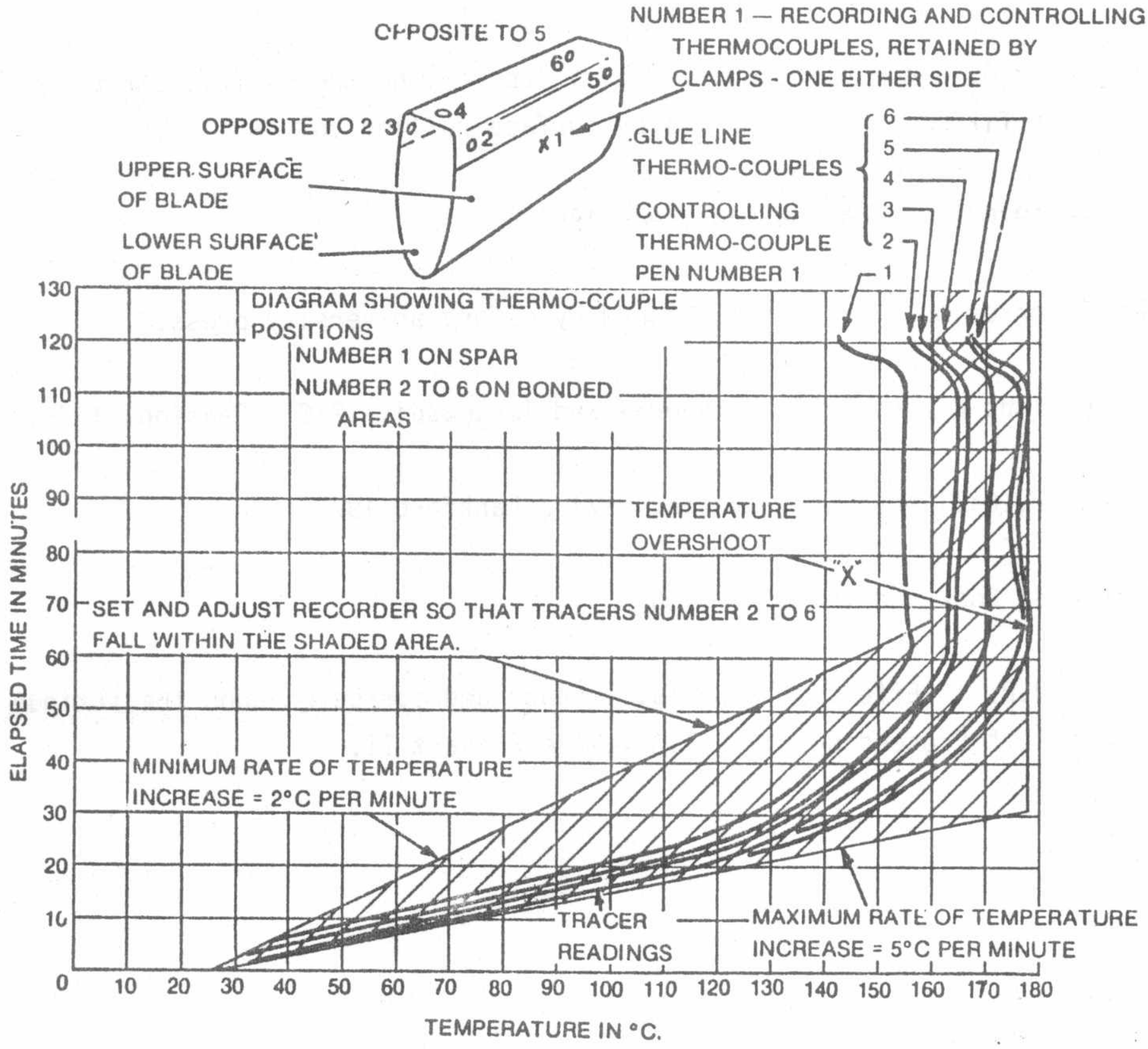


Fig. 4a Temprature Control

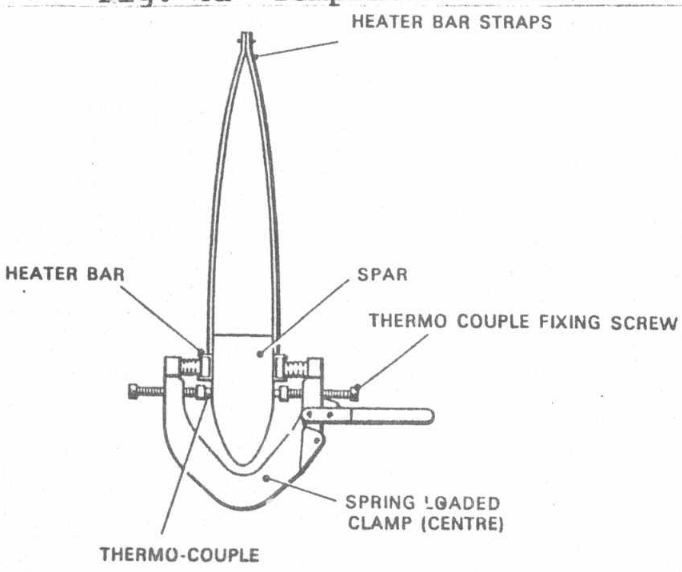


Figure 4b Heater bar location

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