Universal Static Balancing Fixture

For Balancing Rotor Blades

Rotor & Wing Aviation Services P/L

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**Introduction**

Rotor & Wing Aviation Services is an international distributor and technical support company for the Avion Universal Static Balance Fixture (USBF). This is a unique blade-balancing tool which is a digital “virtual” master blade. It is in current service worldwide with the major user being the US Defence Force. This tool solves the age old problem of poorly “matched” blades which have plagued helicopter operators since the inception of wide chord, metal and composite blades.

The concept of the USBF and the technical investigation behind its inception was presented at a HUMS conference held in Melbourne, Australia in February 2001 by Norm Beachum. This conference was sponsored by Defence Scientific & Technology Organisation (DSTO) and the paper was widely accepted as a significant improvement in blade maintenance over that which is currently conducted. This identifies and provides the solution to an age old problem helicopter operators have been experiencing and living with for many years - individual blades which cannot be flown together.

It became apparent to RWAS that the traditional approach to the Rotor Track & Balance problem is more complex than simply looking at the dynamic balance problem in isolation from the entire Rotor balance solution. It is essential to look at the rotor system as a whole when analyzing the vibration solution. The balancing of the rotor system is a straightforward, methodical procedure which MUST start with an accurate static CofG balance - not simply a mass pendulum balance as is often the case, especially common in the teetering head systems. Traditionally, most operators simply perform a comparative balance of the blades. Often each individual blade CofG is different, sometimes significantly so, to that of the original design specification.

Since most dynamic RTB tools provide dynamic solutions which ASSUME each blade is within close tolerance of the original OEM CofG, if any blades do vary outside specified tolerances, the majority of dynamic balance adjustment is consumed by correcting for the static CofG balance problem. This leaves insufficient adjustment remaining to correct for the actual dynamic induced imbalance and confuses the dynamic RTB equipment resulting in poor solutions. Hence it is not uncommon to see move lines come down to a minimum of only 0.15 or even 0.2 IPS before increasing again with further dynamic adjustment. This is a strong indication that the static CofG on one or more blades is significantly different from the rest. This is often attempted to be corrected in two bladed teetering heads with the dynamic solution by use of blade sweep. This has limited authority of adjustment and if blades are significantly different in span CofG, the blades will not be able to be flown together. This difference in span CofG is traditionally caused by either poor blade painting, blade repair, erosion, or trapped water. This is discussed in greater detail in the Avion/AMCOM Report (see download).

**System Description**

The USBF is a one man operated system. It allows even a CH47 blade to be handled by a single person by using a dolly assembly provided. It is now been approved for use on ALL US Army helicopter types.

The blade carriage assembly is approx 20ft long and breaks down into two segments allowing ease of transportability. There is no other support structure or infrastructure
required for the USBF. It is a fully self contained balancing tool as seen below. The USBF can be simply assembled on the hanger floor and balancing commenced. Self contained load cells and computer, weigh the blade, calculate, display and print out the solution. Since the ideal CoF for any helicopter blade is a pure mathematical result of mass and moment arm, the individual blade CoF measured on the USBF is compared with the stored OEM ideal mathematical CoF. The error is calculated and adjustment to the span CoF tip weights provided.

The Blade Balance Problem

Modern helicopter blades have been experiencing difficulties in dynamically balancing some individual blades for many years. This has often led to many wasteful test flights for dynamic Rotor Track & Balance (RTB). Some cumbersome and inventory intensive administrative measures have been utilised to try and overcome these problems at field level by trying to maintain matched sets of blades. Some of these administrative measures have included:

- matching hours of the blades in the set,
- matching serial number, or
- simply by trial & error, flying random blades until a matched set is achieved.

These practices are very time consuming and man hour intensive. Matching blade hours or serial numbers were an attempt to find blades which had “worn” at a similar rate. There have been many theories postulated over the years as to what we were REALLY trying to match including matching blade flexibility, as a blade gets older. But in reality what we were really trying to match with these methods was in fact the blade’s Span Moment Arm. This is the critical parameter which can adversely affect the outcome of the dynamic RTB - but we were unaware exactly of what we were trying to match and until recently, had no way of measuring a blade’s Span Moment Arm at operator or hanger level in any case.

The USBF now provides an easy, quick solution.

With wide chord composite blades and advanced aerofoils, coupled with a much greater scope for repair, it has become more critical to maintain blades within the designed span moment arm i.e. to get the product of blade weight, times the distance from the mast center of rotation to the blade center of gravity to be equal to the OEM original specification. This is to ensure that there is sufficient dynamic balance adjustment (authority) remaining to
counter any hub misalignment and/or blade aerodynamic imperfections. The dynamic adjustments/solutions are provided by the conventional dynamic RTB equipment currently in use by operators.

Avion has collected the data from a wide sample of OEM and Prime Contractor “master” blades. It has provided overwhelming evidence of significant discrepancies between master blades of the same helicopter types/models. These can be significant enough so as to render the available dynamic balance adjustments inadequate to balance a certain combination or set of blades if the span moment arm is too far removed from the OEM’s original mathematical specification. A copy of a recently released report done jointly by Avion and US Army AMCOM on the results found during this investigation can be downloaded Free from this site. This was presented recently at a Health, Usage & Monitoring Conference held in Melbourne, sponsored by the Defence Science & Technology Organisation.

**The Solution**

If a reliable, simple, accurate and economical digital span/chord static balance tool were to be used at operator level, this would provide a “virtual” master blade – a mathematical model against which all blades could be measured. This would remain constant from one field unit to another – without having to have a physical “master” blade on hand with its inherent errors & disadvantages. This would ensure that all the blades are tightly maintained within the OEM’s original mathematical specification. It would significantly reduce the man hours and flight time that has traditionally been spent on dynamic RTB.

The USBF is a tool which provides such a “virtual” master blade with demonstrated repeatable accuracy which far surpasses current master blade comparison practices. It will enable a “virtual” master blade to be held at more than one location if required, with a guaranteed repeatable accuracy of measurement between the respective USBF tools. This will significantly reduce time out of service and costs of having to ship blades to only one location to carry out a static balance. It allows fast, accurate static balance to be done at operator level. Typically, a static blade imbalance can be diagnosed and corrected within ten minutes – on the hangar floor if required.

Maintaining span moments in the field is critical. This is due to changes in the blade characteristics through its life at operator level and before it gets to its overhaul life. Coats of paint, blade erosion, trapped water (especially if left uncovered in areas of high rainfall) and in-field repairs at operator level can dramatically effect the basic span moment arm of a blade. But with easy access to such a tool as the USBF, this no longer need be a problem. Blade re-painting, small blade repairs, leading edge abrasion strip replacement, etc could all be conducted at operator level with access to the USBF. This alone has the potential for significant savings for blades requiring minor repairs which otherwise would have to be sent (freighted) to an approved blade overhaul contractor.

A virtual master blade can maintain span moment tolerances better than comparative balance/master blade technology. This is especially true when managing multiple depots or repair facilities for any given blade type as the Avion/AMCOM report has found.
**Easy To Read Solutions.**

The USBF displays easy to read, clear cut solutions (by part number) as to what adjustments need to be carried out. Below are examples of the printed solutions provided by the USBF.

A solution for a blade which is 106in-lbs heavier than Spec

Location: HELI
Operator: BLOGGS
Date: 02/26/2002
Time: 14:18:35
Blade Type: UH1
Serial Number: AN52677
S-M=29792 S-CG=142.39 WGT=283.47
C-M=112 C-CG=8.548
UserTipChord 4.92
Remove 5.82 oz from "A12"
Remove a "922-3 Retainer"
Remove 3 "921-1 Weight's" Remove a "AM970-4 Washer"
Remove 4 "AM968PD416's"
Add 6.08 oz to "A34"
Add a "943-5 Retainer"
Add 2 "925-1 Weight's"
Add 2 "943-5 Ret/Wgt's"
Add a "AM970-4 Washer"
Add 2 "AM968PD416's"
Remove 8.54 oz from "B"
Remove a "27-115 Retainer"
Remove 2 "27-1 Weight's"
Remove 5.38 oz from "C12"
Remove a "267-3 Retainer"
Remove 5 "267-3 Ret/Wgt's"
Remove 4 "943-5 Ret/Wgt's"
Remove a "269-1 Washer"
Remove a "AM968PD16"
Predicted values after adjustment
S-M=28866 S-CG=142.46 WGT=282.62
C-M=105 C-CG=8.518

Current Span /Chord Moment, CoF, & Mass

A solution for a blade which is close to "Field" Specs but take a small adjustment if being overhauled or repaired

Location: HELI
Operator: ALAN
Date: 03/27/2002
Time: 09:46:53
Blade Type: SH60
Serial Number: AE27-81168
S-M=35789inlb S-CG=173.78in WGT=286.05lb
C-M=11771inlb CCG=5.711
Good blade by field requirements, Deform tolerances require:
Add 0.56 oz to "Span wghts"
Add a "-103"
Add 3 "AM968-5161's"
Predicted values after adjustment
S-M=35889inlb S-CG=173.72in WGT=286.09lb
C-M=11771inlb CCG=5.711

**Authorised Use.**

The USBF has a world wide user base. It is in widespread use throughout the US. Additional users now include the RAF, Turkish Defence Force and Australian Army. Other Defence Forces are also investigating the use of the USBF in streamlining RTB and blade repairs.

The USBF has been given FAA certification for CH46 & 47 for use with Columbia Helicopters.

Increasingly OEM’s are accepting the USBF. It is now being used on all McDonnell Douglas 500 & 600 series factory production blades. Westland have recently announced that they will now use it at factory level on new blades and other Manufacturers are also investigating using the USBF on production blades at factory level.
**OEM Support**

Data collected by Avion comparing master blades of OEM’s & overhaul facilities (Boeing, McDonnell Douglas, Sikorsky & Corpus Christie) was done so under close supervision by both OEM and US Army personnel. Development of the USBF was done with close cooperation of the OEM’s ensuring that Avion had a complete understanding of the master blade concept and OEM blade specifications. Westland have also recently accepted its use on Westland helicopters.

**Effectiveness**

The RAF CH47 fleet currently uses the Helitune Dash 5 and RT2000 RTB equipment and were reporting the normal RTB for CH47 was taking 7-8 plus flights. With the use of the USBF the number of test flights to complete the same dynamic RTB for CH47 has now dropped down to 2-3 flights now that the blades pass regularly over the Avion USBF. Similar effectiveness is reported by all users of the USBF on all types of helicopters. Unusable blades have been recovered back into serviceably inventory to provide dramatic savings.

Benefits recorded from the Australian Army Black Hawk experience indicate a reduction of up to 50-80% in maintenance test flying for time taken for conventional RTB. Most heads now operate with NO dynamic hub weight what-so-ever making dynamic balancing quick, easy and straight forward.

**Aircraft Types**

The USBF is currently being used on all US Army helicopters. A further six USBF’s have been delivered to the RAF in January 2001 for use on their SeaKing, Puma & Lynx. The USBF can be used on all major helicopter rotor blades. This allows the one tool to be used on most, if not all types within fleet operator’s inventory.

**International Support**

International support for the Avion USBF is provided by Avion & RWAS. On-going maintenance and training is available should it be required. Being located in Cairns, Queensland, RWAS has ready access to an international airport which provides easy access to the Asian & Middle Eastern regions enabling rapid response to any of our clients needs.

**USBF Use & Implementation.**

Experience to date has shown that for maximum benefit and cost reduction, it would be recommended that one USBF would be located at each major operating base. This would provide a static balance capability which is otherwise not available at base level. This would ensure all blades are checked and reset back to OEM’s span CofG specs at regular intervals – in the field. This would ensure all blades in field use would be quickly reset and maintained close to OEM blade specs and eliminate “rogue” blades.

Once the initial resetting of the blades back to the datum CofG has been done, a routine balancing would be adopted to coincide with the aircraft major servicing schedule. The
Static CofG balance does not need to occur as regularly as a dynamic balance. Routine, periodic static balancing ensures that blades remain within original OEM CofG limits with no real increase in maintenance man hours. This procedure results in a significant reduction of time spent on dynamic RTB flights to achieve a balance solution. It will make all blades totally interchangeable and has the potential of significantly reducing the number of blades required in stock, particularly if there are currently blades which cannot be flown on the same head. It would also eliminate the common practice of leaving these blades sitting in the racks virtually unusable awaiting another blade which by chance, it can be flown with, this practice being both manpower and resource intensive. Any “new” blades bought into the blade inventory stock would be passed across the USBF to verify its Span Moment arm and reset if necessary to match the fleet’s blades.

The USBF would enable user level repair & painting of blades without the fear of “rogue” blades developing and ensuring a complete fleetwide interoperability of all rotor blades. This would significantly reduce freight expenditure and down time of blades being shipped to overhaul facilities for a simple static balance problem.

**Cost Benefits**

The USBF provides the most cost effective tool or equipment of any RTB or condition monitoring option on the market today. By implementing a simple but effective change in blade management which incorporates the routine use of the USBF in blade balancing, it has the potential of returning the capital procurement costs in just one blade. If only one, otherwise unusable blade from commonly used helicopters today can be returned to service, this will easily pay the capital procurement costs of a USBF. Any subsequent savings in man hours, flight hours, increased aircraft availability or reduced blade inventories is purely additional savings above and beyond the initial procurement costs.

A report from **US Army Redstone Arsenal** (available as **Free** download) listed on the web provides projected cost savings at the Corpus Christi Aircraft Depot alone to be in the order of US$1Mil per year by adopting the use of the USBF to replace current procedures.

**Demonstration/Information of USBF.**

Avion/RWAS can provide USBF demonstrations if required by arrangement. Demonstration and any further details can be obtained by contacting Rotor & Wing Aviation Services. If further information is required, please **Contact Us**.