THE H145 BEARINGLESS MAIN ROTOR – EARNINGS OF THE H135 HERITAGE

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Abstract

The H135 helicopter family is the first serial helicopter with a Bearingless Main Rotor (BMR) after fully articulated and hingeless systems. Since 1996 the fleet of more than 1.300 aircraft has accumulated over 5 million flight hours. In parallel to this success a series of research projects have coalesced to the current status of the next generation BMR which is now the latest improvement for the H145 type to enter the market in 2020.

The main rotor system of a helicopter has direct effects on a multitude of characteristics which form a set of requirements posing a sophisticated optimization challenge. In the financial category we have the manufacturing cost, which not only drive sales prices for a new helicopter and spare parts but also contribute to the cost of operation for the customer. Technically/operationally the performance – in absolute values as well as in relation to the fuel consumption -, reliability, comfort of ride, compact blade folding and maintainability play an important role. Finally regulatory rules regarding safety and noise are an indispensable base layer.

Solutions acquired encompass several new design solutions: the modular concept by separating the integrated blade of the H135 from the flexbeam/control cuff, a modified attachment area with a reduced flapping hinge offset and a new blade attachment design with bearing laminate. On the manufacturing side the introduction of Liquid Resin Infusion (LRI) technologies for cuff and blade helps to reduce cost while in the aeromechanic field a 5-bladed rotor layout with an advanced, optimized aerodynamic blade improves comfort of ride and performances.

Flight tests have confirmed the expectations of a rotor system with low complexity, well balanced performances and excellent comfort of ride. The gains materialize in form of reduced cost, low weight and diminished maintenance effort and expenses. Due to this combination of benefits and the achieved maturity the H145 will profit from implementation of this next generation BMR.

1. MAIN ROTOR DEVELOPMENT HISTORY AT AIRBUS HELICOPTERS

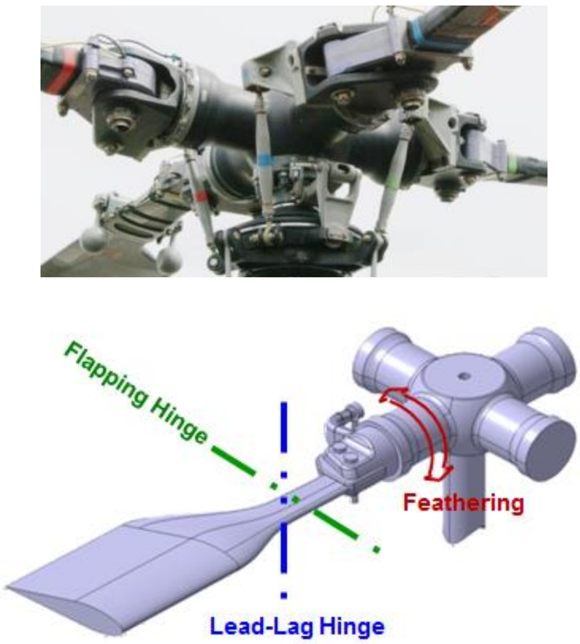
1.1. Bölkow Main Rotor on BO105 and BK117

Over more than 50 years Airbus Helicopters Germany has been working in the field of composites for applications in the dynamic system.

In 1967 the BO105 with its breakthrough design of the hingeless rotor system performed its first flight. Key element of this innovative rotor without articulated mechanical hinges was the composite rotor blade where the flapping and lead-lag motions have been integrated into a flexible blade neck. By using glass fiber composites with high fatigue strength, blades with high life and damage tolerant behavior could be provided for the first time to the market [1].

Due to this tremendous success with the hingeless rotor technology, also the BK117 has been equipped with the “Bölkow” rotor in the late seventies. Over decades many variants of the BK family received this hingeless rotor type with steady improvements. The BK117 first flight took place on 13th June 1979. The successor model EC145 entered into market in 2002 followed by the H145 in 2014.

The latest version is much more powerful and has been equipped with a Fenestron™. The hingeless rotor with its composite blades is operated since 50 years in an outstanding manner on more than 3000 helicopters.



BO105 Hingeless Rotor System

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BK117 – 1979


EC145 – 2002

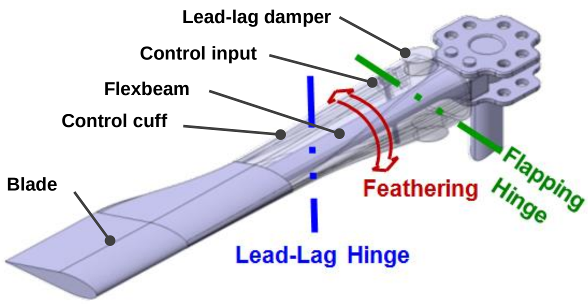

H145 - 2014

The BK117 Family

1.2. The H135 Helicopter Family

The hingeless rotor and especially the composite blades were a great progress in terms of simplification of rotors. Lower masses, easier manufacturing and improved in-service and maintenance behavior with much higher lifetime resulted in reduced operating costs. A trend towards composites for rotor applications could be observed nearly at all manufacturers worldwide. However several oil lubricated bearings and hinges remained on the rotor designs. Therefore quest for further design simplicity arose and in the sixties several research studies for alternative rotor concepts have been launched all over the world.

As an advanced and competitive concept the hinge- and bearingless main rotor system (BMR) has been developed at Airbus Helicopters. All hinges and the blade feathering function were designed with composite elements. Flapping and lead-lag hinges are integrated in an elastic blade neck and additionally the pitch adjustment of the rotor blade is provided by means of a torsionally soft composite flexbeam element. The flexbeam is surrounded by a control cuff which is rigidly connected to the airfoil section of the blade and therefore the blade pitch motion can be transferred from the control rod to the blade. Two elastomeric lead-lag dampers provide sufficient in-plane damping to prevent ground and air resonance.



Principle of a Bearingless Main Rotor System

In the eighties several experimental BMR-systems have been designed and tested on the BO108 technology demonstrator at Airbus Helicopters. The development team had to deal with lead-lag torsion kinematic effects, sufficient force and moment transfer from the rotor blade via the cuff to the damper, axial pretension adjustment of the elastomeric damper in combination with high cuff compression stiffness and several other newly upcoming effects during flight testing. Many new design features were preliminarily implemented and evaluated. Continuous improvements and optimizations at flexbeam, control cuff, damper and interfaces for multiple prototype rotors during the BO108 test phase prepared the successful entry into service of the first serialized EC135 BMR at Airbus Helicopters.

BMR on Whirl Tower and BO108 Prototypes

The EC135 with its 4-bladed BMR system had its maiden flight on 15th February 1994. Mid of 1996 the type certification from LBA, DGAC and FAA has been received. This light twin engine multipurpose helicopter with a MTOW of 2910 kg is used as one of the most preferred helicopters for EMS missions. About 650 of more than 1300 aircraft in service operate for rescue purposes. All EC135 and H135 aircraft have flown more than 5 million flight hours and have demonstrated their reliability and safe behavior.

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The latest variant, the H135 with its series implementation in 2016, has some changes at the drive system and rotor system, resulting in a performance increase of about 20%.

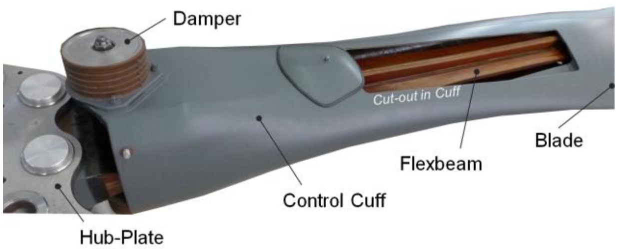
EC135 - 1994

H135 - 2016

The H135 Family

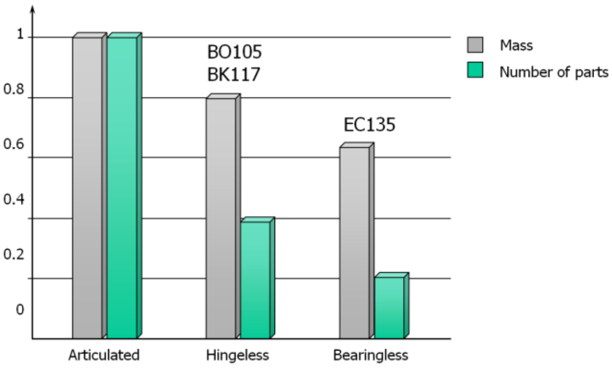
2. BENEFITS OF BEARINGLESS MAIN ROTOR SYSTEMS

More than 20 years in-service experiences exist since the beginning of the EC135 program. About 300 customers in 65 countries operate more than 1300 helicopters with the unique BMR system. Every year 430.000 flight hours are flown all over the world under different environmental conditions.



H135 Bearingless Main Rotor

Compared to other rotor concepts the BMR has generated a significantly lower amount of major incidents during operation. Combined with an extremely low effort for maintenance activities and an on-condition replacement without fixed lifetime for composite parts, the BMR-concept represents the lowest direct operating costs of all rotor systems. The manufacturing seems to be complex and costly however the hub is eliminated. Therefore many parts, bearings, sealings and connecting elements can be omitted. All in all, the manufacturing costs are thus very favourable. The following figure demonstrates the advantages regarding mass and number of parts which represents the complexity of a system. Beside the low maintenance and production cost of our mature Airbus BMR-system, also the masses are highly beneficial.



Comparison of Rotor Concept Complexity

3. AEROMECHANIC CHARACTERISTICS OF AIRBUS HELICOPTERS ROTORS

Aerodynamic effects (unsymmetrical rotor flow, blade vortex interaction, compressibility and dynamic stall effects) during forward flight produce periodic and higher frequency excitations on rotor blades. These loads have to be transferred into the fuselage. Depending on the blade/hub attachment architecture with its stiffness distribution, the characteristics for the transfer of the forces and moments to the hub are predetermined.

As a consequence, the rotor concept and design with its hinge offset affects the properties of a helicopter in terms of [2]:

- Agility or maneuverability
- Controllability, control power behavior
- Comfort, vibration, ride quality and gust sensitivity
- Aeromechanical stability and damping behavior
- Dynamic stability, yaw/roll and longitudinal (Dutch roll and phugoid)
- Pilot-helicopter interface including automatic flight control system impact

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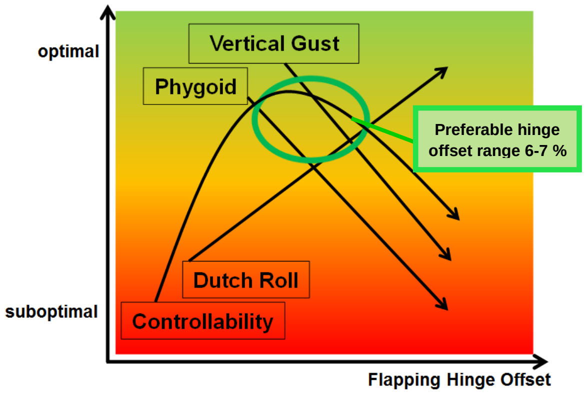
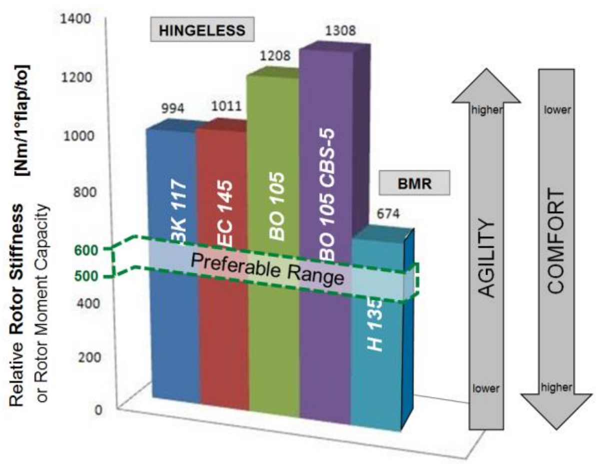
Several topics belong to the Handling Qualities of a helicopter which are essential for the pilot´s task performance for all flight missions. An internal investigation at Airbus Helicopters Deutschland (AHD) has been performed to identify the optimal flapping hinge offset for a multipurpose helicopter. Due to different behavior of agility (controllability), comfort (vertical gust) and stability (Dutch roll and phugoid), the preferable range for the hinge offset has been determined to be about 6-7%



Handling Qualities in Relation to Flapping Hinge Offset

Thus the placing of the hinge offset, which is equivalent to rotor stiffness, influences the agility and comfort of the aircraft. The higher the agility is the lower the comfort and vice versa.

There are different behaviors of the AHD rotor systems. All hingeless rotor systems tend to higher stiffness with higher agility. The H135 blade design corresponds to a rotor stiffness or rotor moment capacity of 674 Nm/1°flap/to which relates to a hinge offset of 8.7% rotor radius. BMRs create an obvious improvement compared to the hingeless rotors toward the preferable range of 500 - 600 Nm/1°flap/to.

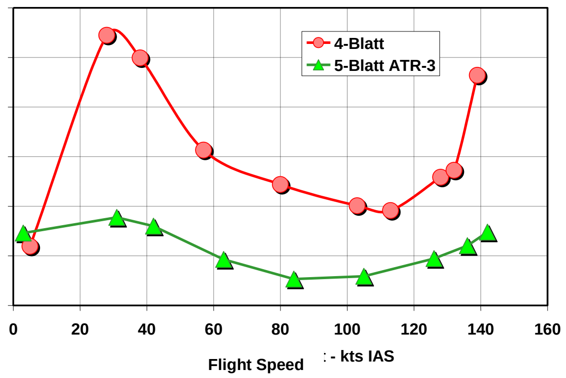


Rotor Stiffness of AHD Rotors

Beside of all aeromechanical properties which are essential for the flight characteristics, one additional important parameter is the number of blades. With the selection “number of blades” the vibration level can be significantly influenced. Due to the corresponding rotor frequency placement, the fuselage response is different.

The higher harmonic air loads of a 5 bladed rotor are reduced to 70% as the essential frequencies 3,4,5/rev of 4 blades are shifted to 4,5,6/rev with 5 blades. In addition, for the blade structural load transmissibility the placement of the 2nd flap bending and 2nd drive train mode is less critical and therefore a further reduction of 50% can be achieved. Finally the human body reacts less sensitive to the increased frequency of 5 blades.

Altogether, 5-bladed main rotor systems create about 70% less vibration than 4-bladed systems.



Vibration Level of a 4-bladed and 5-bladed Rotor [3]

Because of all these facts and findings, the main objectives for all performed research projects described below were consequently a further reduction of flapping hinge offset and it’s applied on a 5-bladed BMR.

Of course, further production and operating cost reductions have been considered as other essential topics for the next generation BMR to be well prepared for the market.

4. SERIES OF RESEARCH PROJECTS FOR THE NEXT GENERATION BMR

Besides the above mentioned general product improvement targets also the change of specific system design parameters have been pursued by setting up the next research projects.

Therefore the continuation of the successful BMR story has to contain chapters about further reduction of maintenance cost, weight and noise while improving performance. In addition flapping hinge offset and number of blades are design drivers for increased comfort of ride.

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The challenge is to follow this multifaceted optimization goal with creativity and new technologies without losing ground in safety and reliability.

4.1. 5-Bladed Advanced Technology Rotor

As a first in the row the Advanced Technology Rotor (ATR) project between 2000 and 2006 aimed at reducing noise, weight, cost and DMC while improving comfort and performance. The answer was a 5-bladed rotor with a modular design concept changing the integrated blade of the H135 into one unit with flexbeam and control cuff (flex-control-unit) and a separate aerodynamic blade. Flexbeam, cuff and blade still maintained the prepreg technology as used in the H135.

Modular BMR with aerodynamic blade and flex-control-unit

The key requirement for the flexbeam was a reduced flapping hinge offset. To achieve this, the root attachment of the flexbeam got a new design concept with two adjacent blades sharing each blade bolt. By reducing the number of bolts to five instead of ten, the attachment radius is reduced and contributes to the flapping hinge offset reduction. In addition the geometry of the thickness tapering between attachment loops and flapping hinge was optimized to shift the flapping hinge further inboard. Altogether the hinge offset changed from 8,7 % of the H135 to 6.5 % with the ATR design.

The new planform of the blade has a negative taper and the proven parabolic blade tip. Newly developed aerodynamic profiles are applied with thicknesses between 12 and 7 % of the chord.

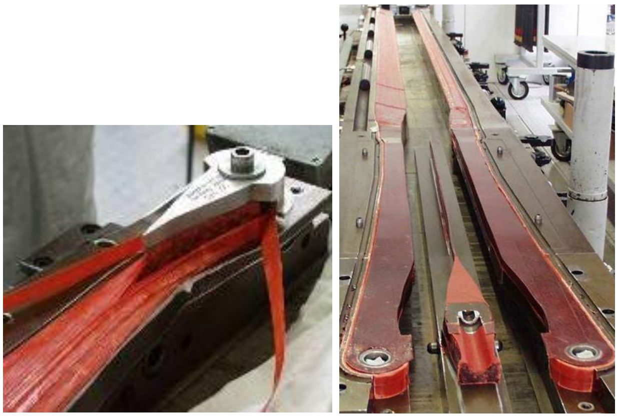
First Flight of the ATR 3 Rotor on 7th April 2006 on an H145 Demonstrator Aircraft [3] [4] [5].

Key elements of the results were a significant reduction in the vibration level even without any additional anti-vibration means thanks to the 5 bladed rotor, and the reduced flapping hinge offset.

4.2. New Low Cost Rotor Blade Concept NEROBA

To further reduce the cost by applying infusion technology to rotor blades a first step was taken by the NEROBA research project [6]. As resin infusion wouldn't be feasible with a loop attachment design in terms of cost and technically sound design solutions, a new blade attachment design with bearing laminate was introduced. This reduces significantly the structural complexity and also the lay-up which opens the door for automated pick and place processes in the manufacturing.

The following figure shows the manufacturing of the state-of-the-art design for a loop attachment element. On the left there is a detail of the lay-up for one of the four loops which establish the attachment design of the H135. Each of the several hundred unidirectional prepreg roving strands is positioned and draped manually around the attachment bushing location and placed into the mold extending along the spar – at maximum up to the blade tip as seen on the right. Here also the preparation of the lower half of the spar can be seen, composed of two loops with their spar contribution complemented with web layers and spacer elements between them.



Manufacturing of H135 Flexbeam and Blade Spar

Obviously the high amount of manual work and the relatively high price of prepreg material present a cost reduction potential if the lay-up could be simplified and the added value of resin impregnation is in-sourced. The modularity of the new rotor allows applying this to the blade attachment which had for the ATR a loop design similar to the above shown H135 blade.

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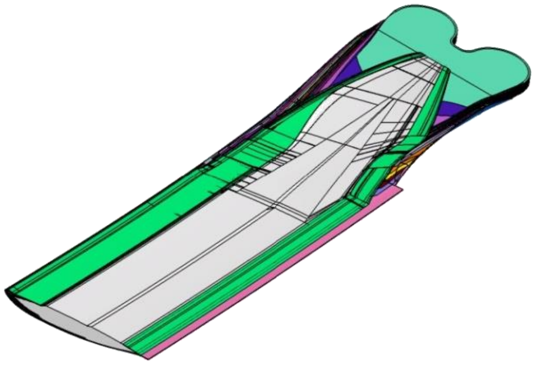
Elementary technology bricks were elaborated in the field of manufacturing technology, design and stress analysis. These encompassed the investigation of preform technologies like automated cutting, placing and draping as well as infusion simulations and manufacturing studies of structural features like attachment area and aerodynamic profile sections.



Flat Lay-up of the NEROBA Blade Attachment Area

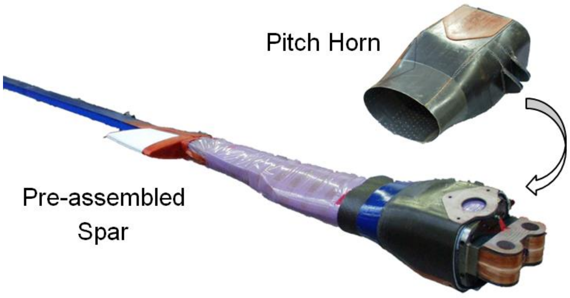
The design of the blade was adapted to the specifics of the infusion technology. Also strength substantiation constituents including simulation methods and tools, basic material data and subcomponent tests for bearing laminates were established.

The first injection of a complete rotor blade was successfully performed in 2007 and clearly confirmed the feasibility of this technology for application to this kind of structures.

Blade with Bearing Laminate Attachment without Loops

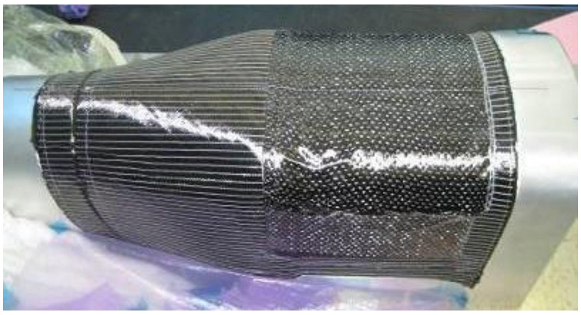
4.3. Optimized Control Cuff - PRECARBI

In a second step the infusion technology was extended to the pitch horn of the H135 BMR control cuff by the PRECARBI project. The figure below shows the combination of the cured spar with the cured pitch horn. They are then molded together with the common control cuff and blade skin and all other blade constituents to form the complete integrated H135 rotor blade.



Combination of Spar and Pitch Horn of the H135

A manufacturing process for a rotor blade pitch horn in preform technology has been developed and validated. The process incorporates the use of automated production techniques. Planar Tailored Reinforcements (TR) are manufactured in a 2D-stitching portal followed by an automated cutting operation. These TR are then formed to a Sub-Preform representing one half of a pitch horn.



Sub-Preform for One Half Pitch Horn

Two Sub-Preforms are assembled in a tool and infusion is conducted.

The manufacturing time and material cost savings compared to the prepreg process were quantified to be more than 20% by the analyses performed within the project.

Complete Pitch Horn

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4.4. Low Cost Advanced Rotor LoCAR (2009 – 2011)

For the integrated H135 blade the pre-manufactured pitch horn is assembled on the flexbeam and then the blade airfoil region and control cuff) structure is laid up and cured altogether.

Manufacturing of the Control Cuff for H135

As a further and third step, building on the experiences of the infusion molded pitch horn and blade these manufacturing technologies were applied to the complete control cuff and further refined and industrialized.

In addition the flexbeam design was further developed to improve structural performance and manufacturability.

Separate Cuff Manufactured in Infusion Technology

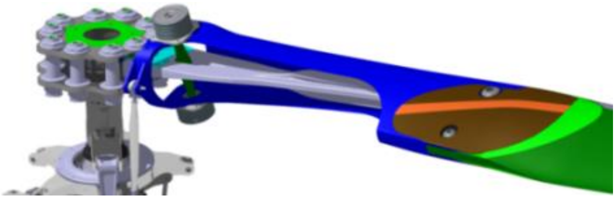
Simultaneously the infusion technology was used to manufacture a rotor blade in the new Blue Edge™ design. It could be shown that the infusion is also applicable for this more complex interior design and also the characteristics on this kind of blade in terms of cost, noise emission, loads and performance have been evaluated.

LoCAR Main Rotor Blade manufactured in Infusion Technology

Obviously the modularity of the rotor made it necessary to take special care of the load transfer and stiffness requirements at the separation between the blade and the flex-control-unit as well as at the connection between flexbeam and cuff at their outboard end.

Prepreg Flexbeam

The resulting higher complexity of the flexbeam compared to the one of the H135 led to a cost increase of the flexbeam of 23 % while the benefits of the injection process reduced the cost of the control cuff by 22 %. In total the flex-control-unit is 2 % less expensive than the respective integrated portions of the H135 blade. Taking into account the benefits of the modularity, the system has significantly gained cost efficiency.



LoCAR BMR System

4.5. Bluecopter GHD

After having the assuredness that all crucial elements for a next generation BMR are feasible and promising this rotor system got airborne in 2013 on the technology demonstrator Green Helicopter Demonstrator (GHD).

The Green Helicopter Demonstrator GHD

GHD Fenestron™ and Shroud with T-Tail

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In addition to the new BMR the GHD integrated other technological elements like e.g. a new low noise Fenestron™ design, a modernized shroud with T-tail, a main rotor head full fairing, improved aerodynamic fairings and shaping of the airframe and a low RPM definition.

With the help of all these technological elements the GDH succeeded in being the benchmark in noise (8-10 EPNdB below ICAO Limits), performance (8-14 % less power required) and fuel consumption (-12 %).

4.6. Merge to Next Generation BMR GRC1 Demonstrator

Experiences from all the previously mentioned research projects have been merged within the frame of the European research project CLEAN SKY for the Green RotorCraft (GRC1) subproject.

The designated demonstrator was the "Bluecopter" aircraft which is based on an H135. Related to this baseline the targets were to make the ARIS (Anti-Resonance-Isolation-System) obsolete, to improve vibrations and comfort of ride even without the ARIS, to reduce the overall system weight and finally to establish an aerodynamic blade layout.

In order to combine the superior dynamic characteristics of the ATR rotor with the aerodynamic and aero-acoustic gains of the Bluecopter main rotor, the GRC1 main rotor demonstrator was developed as next evolutionary step with a similar planform as the ATR rotor. Here the best compromise between performance, weight, costs, loads and acoustics have been discovered.

The GRC1 Main Rotor Blade

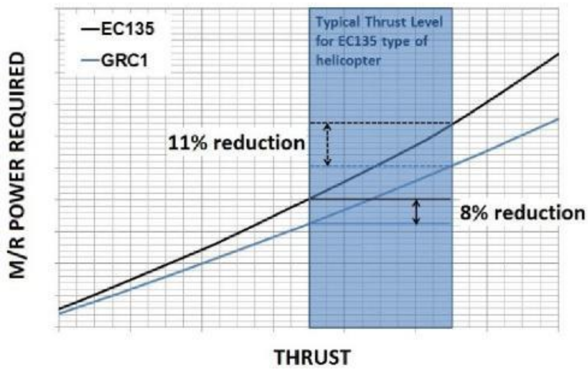
The fine-tuning contained additionally a careful blade mode frequency placement, taking over from Bluecopter the superior kinematics of control and lead-lag damper.

The GRC1 rotor was first flown on our Airbus Helicopter demonstrator "Bluecopter" on 4th August 2016.

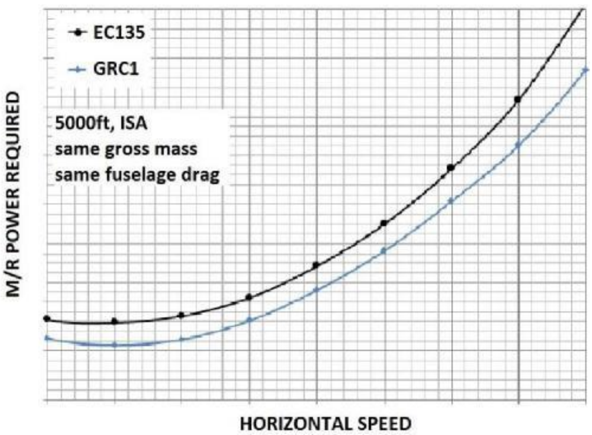
GRC1 Rotor Flying on the Bluecopter Demonstrator

Results from the flight tests showed that the design targets envisaged by the development team and predicted by the simulation were achieved.

The power demand in hover conditions as well as in forward flight is significantly reduced compared to the baseline aircraft H135.



Power Required GRC1 vs EC135 Main Rotor (HOGE, 10000ft, ISA)



Power Required of GRC1 vs EC135 Main Rotor

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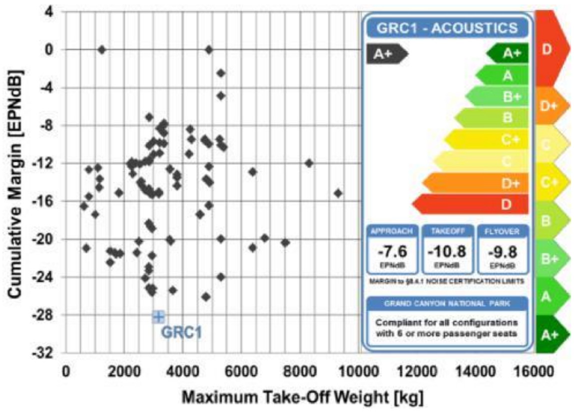
Considering the cumulative margin versus the ICAO noise certification limits (Chapter 8.4.1 / 11.4.1), illustrated below, the Bluecopter with the GRC1 rotor is the first and only helicopter to reach the A+ rating [7].



Green Metrics Philosophy

To make immediate use of the final results achieved in the above mentioned chain of research projects it was decided in March 2017 to launch a Proof of Concept (PoC) phase for application of the GRC1 rotor on the H145. After only 5 months the first flight in the PoC phase was performed on 7th August 2017.

The PoC phase was concluded end of 2017 after a dedicated flight test program and performance analysis. All the predicted benefits have been confirmed and led to the program decision to start the serialization of the next generation BMR for the H145.

5. THE NEXT GENERATION BEARINGLESS MAIN ROTOR H145 "HIGH FIVE"

5.1. Decision for Serial Development

H145 with 5-bladed BMR

After 15 years extensive research activities on the BMR with the successful final proof of the GRC1 rotor on the H145, the serialization of this 5-bladed BMR has been decided.

In April 2018 the official project launch with partner Kawasaki was initiated at the Berlin Air Show. Based on extensive flight tests including hot/high and cold weather campaign and preliminarily performed component fatigue tests with the most important parts, the design including the manufacturing process of the rotor and the aircraft could be frozen mid of 2018. Finally the new H145 with the 5-bladed rotor was going public in March 2019 on the Heli-Expo in Atlanta. With the new generation BMR on the H145 "High Five", Airbus Helicopters is confident to succeed in providing exactly the market needs for a light twin helicopter.

The next steps are [8]:

- Avionics Software Development incl. AFCS tuning
- Start of flight test with second prototype for confirmation of loads, performance
- Component strength and fatigue tests
- Preparation of certification files
- Preparation of GSE, Technical Documentation, Manuals etc.
- Development of customer optionals
- Implementation of the blade folding capability
- Certification with EASA in first half 2020
- Entry in Service mid of 2020

5.2. H145 "High Five" Features

General

H145 "High Five"

With the launch of the Airbus Helicopters five-bladed version of its H145 light twin, an increase of 150 kilograms useful load over the existing aircraft version has been evolved for the operators while preserving the outstanding performance characteristics. The comfort of ride and the vibration level have been significantly improved due to the use of a 5-bladed rotor with reduced flapping hinge offset. The new BMR reduces maintenance and will increase the availability rate of the helicopter.

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The H145 "High Five" features in detail:

- New advanced 5-bladed BMR
- MTOW increase by 100 kg to 3800 kg
- Rotor system weight reduction by 50 kg
- Empty weight to MTOW ratio close to 50%
- Reduction of vibration level and elimination of all anti-vibration means in H/C
- Improved comfort behavior due to reduced flapping hinge offset
- Removal of 3 Hz skid dampers
- Reduction of DMC by lower maintenance effort for the BMR and reduced number of parts
- Slightly decreased rotor diameter from 11,0 m to 10,8 m
- Elongated mast (100 mm) due to clearance aspects as a consequence of "softer" blade
- Compact blade folding option
- Same D-2 speed and range
- D-2 low noise signature unchanged
- HELIONIX and wACS (wireless airborne communication system) enabling easy data collection and fleet analysis

Mass and Cost

It is a widespread misconception that a 5-bladed rotor system is heavier than one with 4 blades. Taken into account the whole system including anti-vibration means to achieve similar vibration levels, 5-bladed systems have less weight. Especially the tuning of 4 blades for the second flapping mode requires considerable tuning masses which are not necessary for 5 blades.

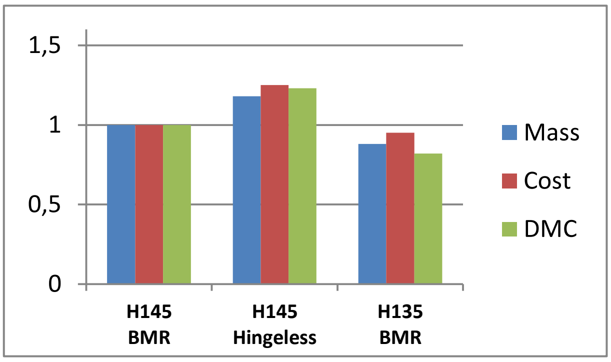
Despite of a necessary auxiliary electrical pump and stiffness/weight adaptation for front cross tube of landing skid and horizontal stabilizer, the total mass breakdown for the H145 "High Five" provides savings of 50 kg as shown in following table.

	Removed parts	Added parts	Delta mass
Main Rotor Blades	- 191	+ 221	+ 30
Rotor Hub + Mast	- 111	+53	- 58
Anti-Vibration Dev.	- 27		- 27
3 Hz Skid Damper	- 11		- 11
Hydr. Power Supply	- 36	+38	+ 2
Landing Gear (fwd. tube)	-59	+60	+ 1
Flight Control System	- 46	+ 51	+ 5
Bird Strike		+ 2	+ 2
Others		+ 6	+ 6
Sum	**- 481**	**+ 431**	**- 50**

Weight Saving in [kg]

Of course the cost of parts and the maintenance effort are key elements for a technological choice, as they directly enter into the customer benefit. The following table shows the comparison between the new H145 BMR, the current Hingeless rotor system of the H145 and the H135 BMR. Considering the different rotor technologies and MTOW, it is obvious that the new "High Five" BMR demonstrates outstanding values.

	H145 BMR 5 blades - 3,8 to	H145 Hingeless 4 blades LAVCS 3,7 to	H135 BMR 4 blades ARIS 2,9 to
Mass	1	1,18	0,88
Cost	1	1,25	0,95
DMC	1	1,23	0,82



Weight and Cost Comparison
for Rotor System incl. Anti-Vibration Means

It is evident, that compared to the H135 with the fully integrated blade and a 4 bladed rotor, the weight and cost increase is in accordance with the modular design and the 5th blade. However it has to be noted that the increased aerodynamic capability of the new BMR will offer significant growth potential.

In relation of the existing H145 to the new BMR, the rotor head functions being realized in composite material and the reduced number of parts per blade lead to significant reduction in weight, cost and maintenance effort which even overcompensate the addition of one blade.

Performance

Despite of adding a fifth blade and the slight reduction of rotor diameter, the performance at HIGE, HOGE, level flight, climb and speed up to v_h is within the normal scatter of H145 serial helicopters with 4-bladed hingeless system.

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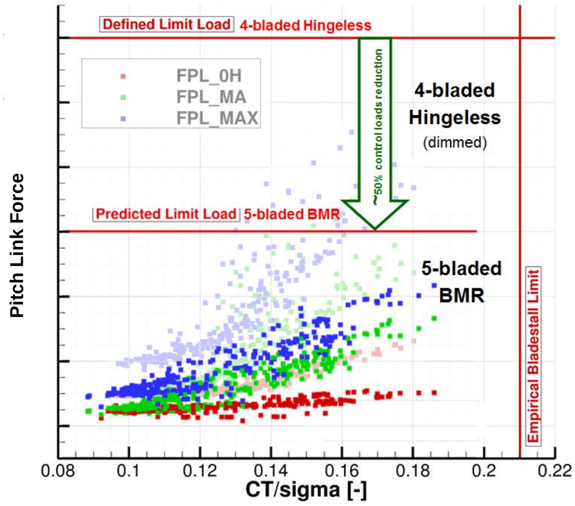
Loads

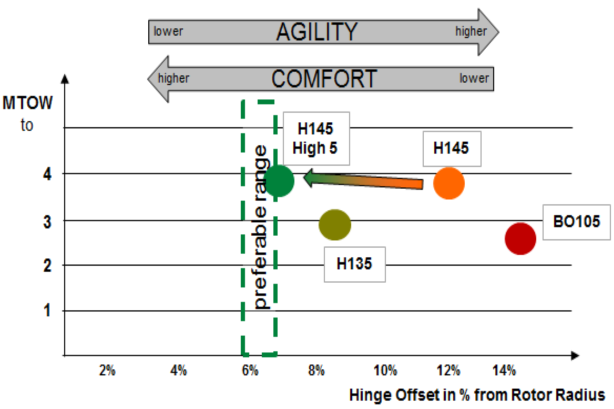
The hub loads in the stationary flight conditions are comparable between H145 four and five bladed rotor as they are mainly influenced by the fuselage configuration. However, the limit load of the main rotor mast moment could be reduced by ~30% due to reduced flapping hinge offset. The control loads of each blade could be reduced by about 50% due to modern airfoils and advanced blade geometry.



Reduction of Control Loads with 5-bladed BMR

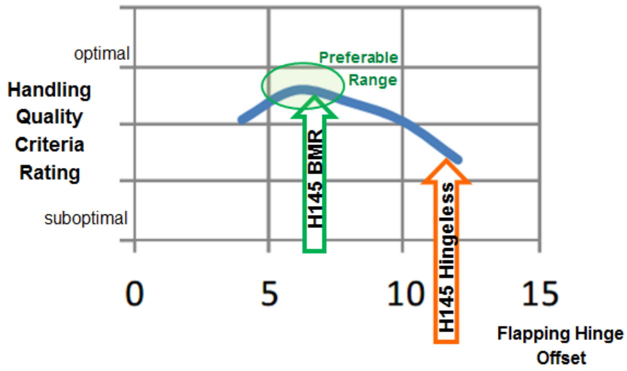
Handling Qualities

The hinge offset of the H145 "High Five" BMR is located at 7,0% rotor radius. This means a reduction of 20% compared to the H135 BMR and even more than 40% to the H145 with the hingeless rotor. The relative rotor stiffness or mast moment capacity, as described in chapter 3, for the H145 BMR was determined to be 575 Nm/1°flap/to which is excellently in line with the recommendation of 500 - 600 Nm/1°flap/to.



Hinge Offsets of AH Helicopters

Considering the aeromechanic characteristics and the consequential behavior of the helicopter, the hinge offset with 7% is located in the preferable range.

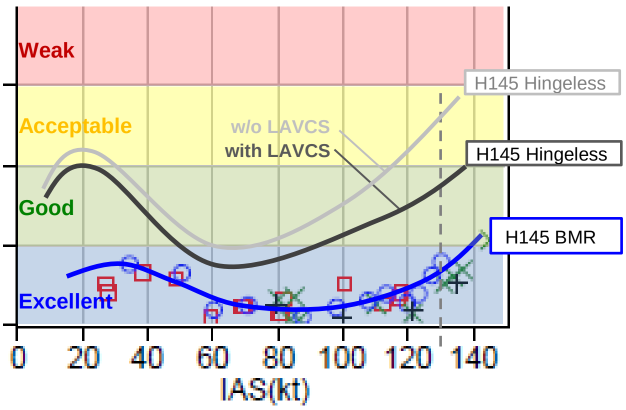


Excellent Handling Qualities of H145 BMR

With respect to the handling qualities, an optimum between agility, controllability, gust sensitivity and stability criteria has been reached and provides high comfort with a smooth ride.

Vibration

Due to the 5 bladed rotor design with the beneficial main rotor frequency placement, the fuselage response and therefore the vibration level of the H145 helicopter has been improved even though the light active vibration control system (LAVCS) under cabin floor has been removed.



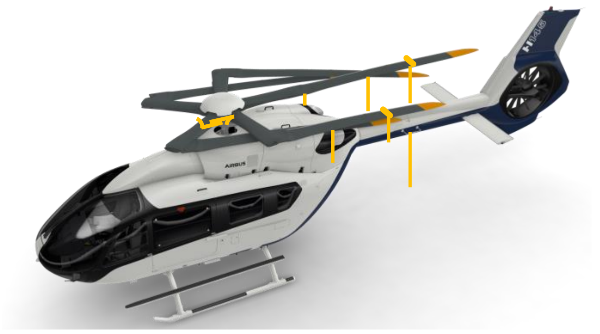
H145 Cabin Vibration Level

Noise

The noise measurements with respect to ICAO Annex 16, Chpt. 8 for helicopters have been preliminarily performed in April 2018. The noise level is expected to be in comparable low magnitude, and well below the ICAO-limits.

5.3. Folding Capability

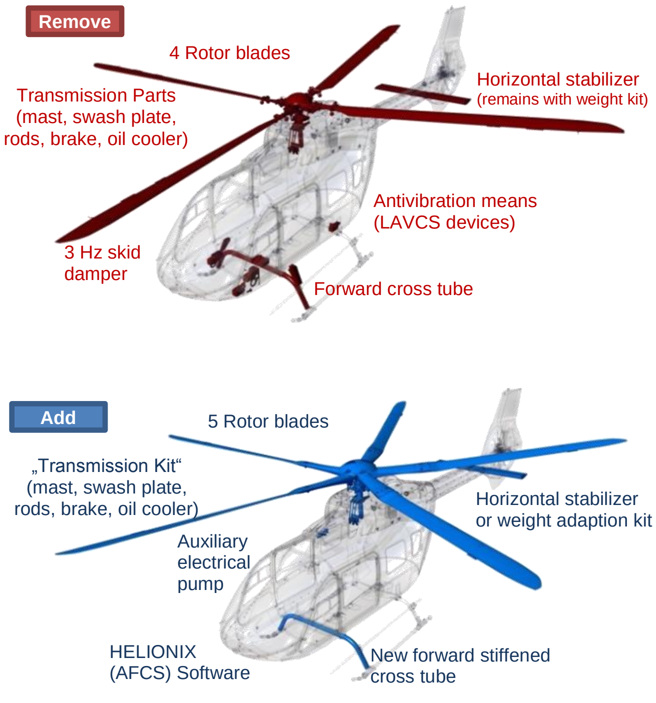
The 5-bladed BMR for the H145 with its special blade connection feature to the flex-control-unit will provide a compact folding with all blades to the aft. The blades are capable to fold around the main and secondary blade bolt in both directions. If the folding will be required by the customer, the provisions could be retrofitted on the normal serial rotor. The kit will contain beside a mechanical rework of the blades/cuffs and an installation of fixed provisions on the tail boom, folding poles with quick release blade supports, locking torque devices and all necessary utility tools.



H145 with Folded 5-Blade Rotor

5.4. Upgrade from D-2 to D-3

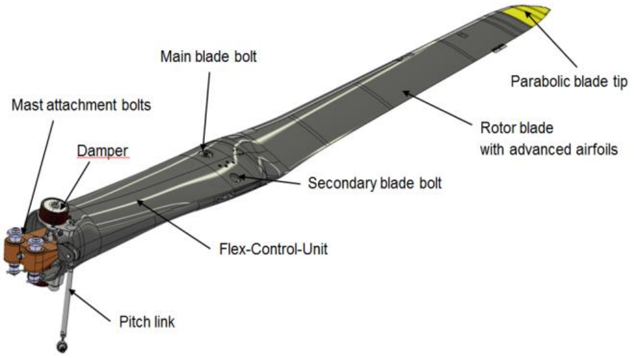
An H145-upgrade is possible from 4-bladed hinge-less to a 5-bladed BMR system. The airframe, tail-boom, cowlings, engines and gear box are basically unchanged. Several components could be removed and on the other hand, parts have to be modified, added or replaced as the following figure demonstrates.



Upgrade Concept

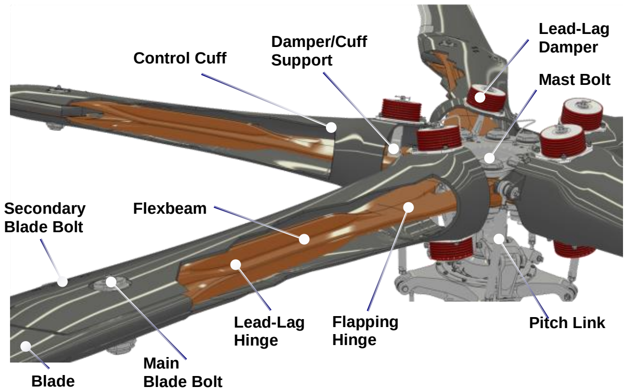
5.5. Rotor Design Elements

A flat blade connection with main and secondary blade bolt attachment has been implemented which enables advanced and low cost production methods for the blade and cuff. In addition, the maintenance effort could be reduced and a highly beneficial blade folding “all blades aft” could be provided.



H145 Blade with Flex-Control-Unit

The consequent continuation of the H135 BMR technology through several research projects and using all lessons learned experiences from the operation led to the final development of the H145 5-bladed rotor. The basic flexbeam with its flapping and lead-lag hinges has been optimized regarding geometry and used materials. The stiffness design as well as the load and kinematic transfer were adapted in such a manner that the same lead-lag dampers of the H135 can be used. All in all, proven BMR technology has been transferred into the H145 BMR.



Elements of the new H145 BMR

Presented at 45th European Rotorcraft Forum, Warsaw, Poland, 17-20 September, 2019

6. SUMMARY

H145 "High Five" BMR

The H145 "High Five" rotor provides the most advanced BMR-technology developed by Airbus Helicopters where all the in-service experience of the H135 family and findings of several research programs have been implemented. Due to the consequent use of modern production technologies including Liquid Resin Infusion the costs could be kept low. As already demonstrated by the H135 BMR, this rotor technology with its sophisticated application of composites promises very low maintenance effort. The comfort of ride and vibration level of this new H145 could be extremely improved due to lowering the hinge offset and use of 5 blades. This "High Five" BMR sets a new standard in rotor technology.

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