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# INTERMESHING ROTOR HELICOPTER "KAMAN K-MAX"

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## ABSTRACT

This paper describes the design, performance and applications of an American intermeshing rotor helicopter "Kaman K-max" developed by Kaman Aerosystems. Initially designed for USAF (United States Air Force) as HH-43 Huskie during the cold war and later developed as Kaman K-max. Specifically conceived and designed for repetitively lifting external weights its design is one of the few but optimum sky crane designs available in the market today. Identified by its unusual appearance of intermeshed rotor arrangement is what makes it outstand amongst other helicopters. Inculcating the benefits of these intermeshing rotors, eliminating the need of tail rotors, and providing greater field of view during lifting adds to its value. Many rotor experts are interested in the fascinating yet challenging study of these intermeshed rotors and many researches are being undertaken to further enhance its performance.

## I. INTRODUCTION

Intermeshing rotor helicopter's configuration is also known as "synchropter". The helicopters with this configuration consist of set of two rotors rotating in direction opposite to each other and attached to two separate masts which are aligned at particular symmetrical angles so that the rotors while rotating do not collide with each other. To ensure that the rotors do not collide, the swash plates and complex linkage gear boxes play the major role by controlling the blade pitch for each rotor and by providing them different pitch angles depending upon the forward speed, yaw and roll control. Most of the helicopters in this category have only two blades one on each mast (also known as twin intermeshing) but some models like Kellett XR-10 falls into exception with 3 intermeshing rotors. The blades on the mast do not directly contribute to vertical lifts due to the fact of being arranged at an angle to the vertical, also aerodynamically interfering with each other at high speeds hinder their efficiencies, but on the other hand this configuration supports the tail less configuration of the helicopter which saves power. Despite not having tail rotor drive system, the configuration generates yawing moment by increasing collective pitch at any one of the two rotors and varying the torque. The Germans were the ones who started developing for this intermeshing rotor technology during World War 2, and later was further developed with new technological advancements by the American Army during the Cold War. Helicopter models which fall into this category and developed by Kaman Aerospace Corporation are Kaman K-225, Kaman K-700, Kaman HH-43 Huskie, Kaman K-max (Kaman K-12000) and more. Milestone was set and recognition found for these helicopters in the year 1951 when one the prototype of Kaman K-225 was experimented by attaching a turbo-shaft engine and became one of the world's first helicopters to be powered by a gas-turbine. Out of all these helicopters Kaman K-max is the technologically most advanced and practically most efficient model among its counterparts whose design, performance and applications will be discussed here. This helicopter was specifically designed and tested for repeated lifting of heavy external loads and it can lift up to 6000lbs which is more than its own empty weight and thus commonly referred to as an "Air Truck" or "Air Crane" due its efficiency of lifting external cargo loads. For the fact that Kaman K-max is a synchropter therefore it has a natural tendency of hovering at a place for longer durations (due to increased stability), having no tail causes all the engine power to be delivered directly to the main rotor giving it increased lifting capability, to act instantaneously to the pilot's command, making it very much suitable for rescue operations. Also, the most recent advancement of developing an unmanned version of this helicopter (optionally piloted) in collaboration with Lockheed Martin, and using it in war with Afghanistan by USA has made it the most accurate and compact in size helicopter to be used in a war.

## II. DESIGN

- **Main Rotors:** As discussed earlier that Kaman K-max uses counter-rotating intermeshing rotors which not wasting any power to the anti-torque converts all into lift.

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- **Tail Rotor:** Using intermeshing rotors eliminate the need of tail rotors and yaw is controlled by varying the pitch of one of the blades.
- **Controller:** Servo-flap controlled rotor blades which aerodynamically controls blade twist and placed at 2/3rd of the trailing edge of the blades so that the pilot without the need of any intermediate systems such as electrical or hydraulic have a direct link with them.
- **Passenger and seat:** The company has tried to keep its design simple and surreal by keeping only one passenger seat cabin and tried to reduce the extra systems so that the linkage between the engine and the main rotor can be well established.
- **Engine and fuel:** This helicopter uses T53-17 turbine engine with very minimal fuel to spare, burning only 82 gallons of fuel/hr.
- **Airframe:** This helicopter has a narrow and a kind of tapered profile to enhance pilot's visibility with unique landing gear placement along with very strong fuselage made up of aluminium (covering important regions like fuel tanks & cockpit) and enhanced airframe strength that is durable and bears loads due to stresses occurring between the main rotor and the cargo hook during operations of lifting. Also suitable for operations in elevated heights and temperatures.
- **Window panels:** Angled side windows with bubbled glass further improve field of view of pilot during operations. Also, the pilot almost sits above the side window with all controls by his side.
- **Cargo-hook assembly & trolley:** The helicopters in the Kaman series are all built by surrounding the cargo-hook as the center piece and works by a distinctive trolley system. This system allows the hook to move in a to-and-fro motion about the center of the aircraft maintaining stability for both aircraft and loads. The cargo hook remains in a curved shaped track whose structure is heavily reinforced and provides reliable lifting.
- **Vertical reference flight:** Unlike the conventional helicopters in Kaman K-max an external instrument panel is deliberately installed outside the cockpit in the pilot's view to allow pilot to anytime monitor the performance parameters of the aircraft during operations with the utmost ease.
- **Safety & reliability:** As there is no tail rotor it means that there will be very minimal downwash which provides safer flight and ground operations. The fuel system is made crash resistant. 5-pt. pilot restraining system.
- **Noise level:** Due to no tail rotors the noise levels are very much lower than the conventional helicopters.
- **Maintenance:** Due to the fact that it do not consist of a lot of extra aircraft systems (e.g. hydraulic control system) and having a simple design, hence it requires very less maintenance.
- **Other design specifications:**

| | |
|---|---|
| Empty Weight | 2334 Kg |
| Useful load | 3109 Kg |
| Max. gross wt. (with ex. load) | 5443 Kg |
| Max. gross wt. (without ex. load) | 2948 Kg |
| Cargo hook capacity | 2722 Kg |

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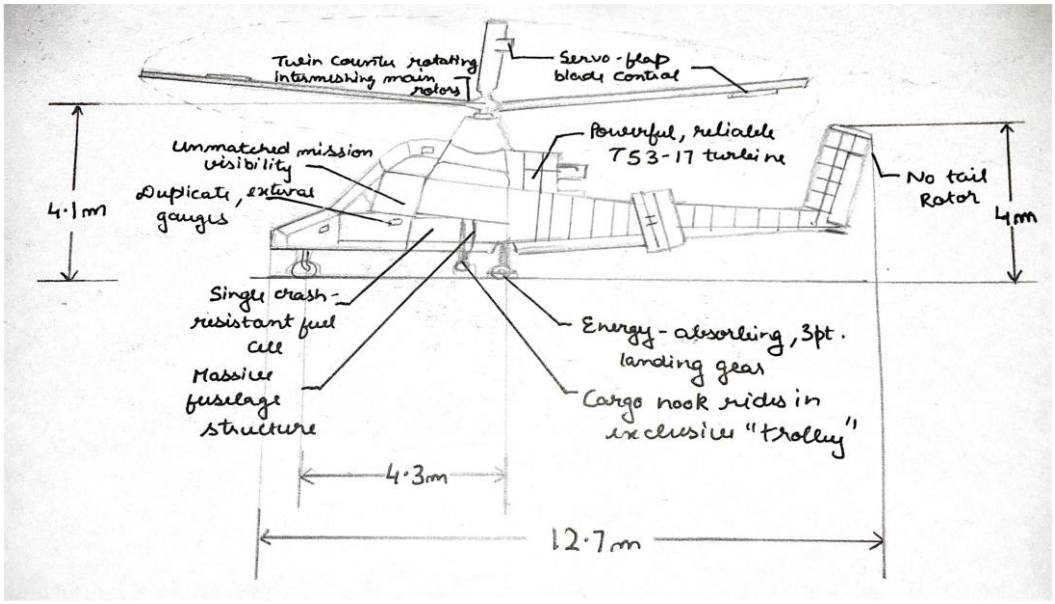


**Fig.-1:** Side view of Kaman K-max

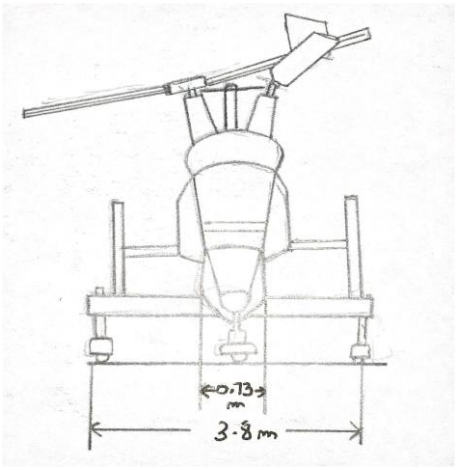


**Fig.-2:** Front view of Kaman K-max

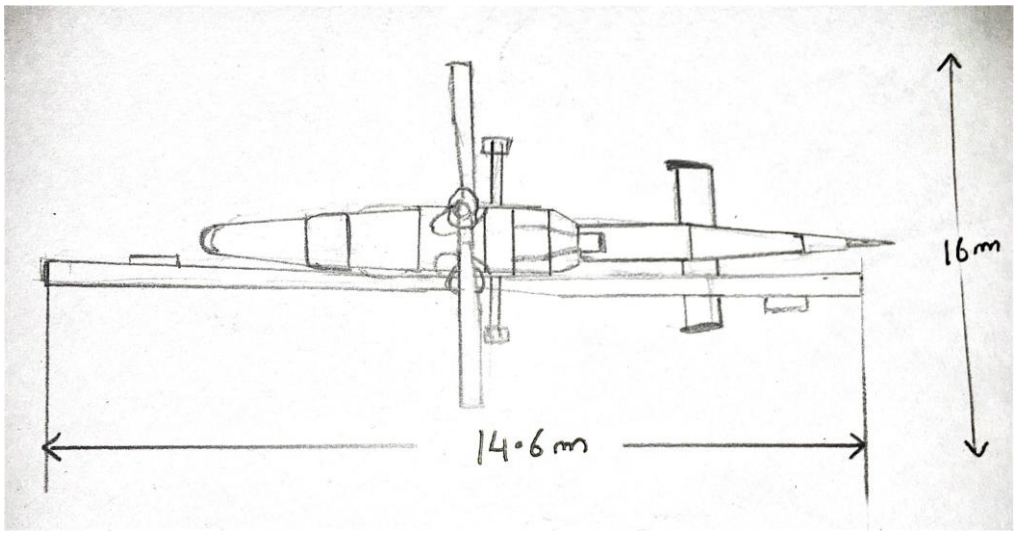


**Fig.-3:** Top view of Kaman K-max

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## III. PERFORMANCE PARAMETERS

- **Lift:** As already discussed that being without a tail rotor the power for this aircraft directly goes to the main rotors enhancing its lift capacity but on the other hand the rotor blades contributes less to the vertical lift component as compared to other conventional counterparts.
  Whereas very high performance helicopters such as Agusta 109E flies at an altitude of 10,400ft the lift performance for Kaman K-max varies from 2722Kg of lift at sea level to 1960Kg of lift at 15000ft.
- **Hover:** Being from the family of synchropters, Kaman K-max provides an exceptionally high natural stability making it perfect to hover at some particular altitude for longer durations.
  Talking about the hover performance at an altitude of 4000ft the hovering ability IGE (In Ground Effect) is about 5443 Kg and hovering ability OGE (Out of Ground Effect) is 5216 Kg.
- **Power plant:** The engine used for this Kaman K-max is Honeywell T53-17 gas turbine engine with a shaft power of 1800 HP.
- **Fuel system and fuel consumption:** The approved fuels used by Kaman K-max includes Jet A, Jet A1, Jet B, Jet-4/5/8. The fuel system consists of a total fuel capacity of 865 liters and total usable fuel of 831 liters. It has a very efficient lift to fuel ratio as compared to the other helicopters in its league i.e. about 310.4 l/hr.
- **Endurance performance:** W/o fuel reserve the maximum endurance achieved by Kaman K-max is about 2hr+41min.
- **Range performance:** Maximum range achieved by this helicopter with external loading is 396Km and without external loading is 495Km.
- **Airspeed:** The maximum air-speed achieved by this helicopter with and without loading is 148 Km/hr and 185 Km/hr respectively.

## IV. APPLICATIONS

Discussions made earlier suggests that higher flight and hover stability and spontaneous actions undertaken by the helicopter on pilot's command along with the addition of the design of its airframe and windows to provide maximum possible field of view to the pilot during operations. Also inculcation of VRF (Vertical reference flight) outside the cabin, its compact size and lowest noise production makes it the most practical solution for rescue, warfare and other operations available in the market today. There are plethora of applications provided by Kaman K-max in various fields as discussed here in brief:

- **EMERGENCY RESPONSES:**

a) **Extinguishing fires:** As we know that Kaman K-max can work in high temperature surroundings and also high lift capacities allow it to carry significant amounts of water to the affected areas such as during forest fires (on mountains) and can also refill water carrier from nearby sources within a short span of time and dropping it on exact locations.

b) **Disaster relief and rescue operations**: During natural calamities such as floods or earthquakes when the people of the affected areas get disconnected from rest of the world, this aircraft plays a major role in providing relief supplies and other necessary aids. As the land transportation is the one which gets most affected during such times hence this aerial help is the call for relief. Also, during situations like landslides and earthquakes due to its ability of heavy lifting and work for longer hours made it the perfect helicopter to rescue people stuck under disintegrated high rise buildings by removing debris.

c) **Defense**: As already discussed that the new version of Kaman K-max as an UAV (Unmanned aerial vehicle) has been used in war situations to supply war-supplies to the main base. It also helps to prevent casualty during war and proves to be an asset to any force as it can be strategically deployed because of its very low noise feature. This is a low maintenance but high performance equipment any force can have.

d) **Timber harvesting**: Its one of the earlier applications was to be used as an aircraft to transport logs from forests to the timber landing sites. These aircrafts are being used till date for the same as these are the most effective and cost saving transportation for timber industries.

e) **Repair and constructions of power lines**: The high rise power lines and towers demand such transports that can carry heavy concrete poles and help in their erect placements, also to take long power supply lines

from one pole to other. These demands are fulfilled easily by the Kaman K-max. It also helps the electrical mechanics to reach to these high rise poles easily for their further maintenance and repair.

f) **Construction (oil rigs, Pipelines, ski lift etc.)** : These aircrafts proved to be a great asset to the construction industry say the constructions of oil rigs that require transportation of very heavy foundation pillars to transported to the deep sea regions, while spreading pipelines in the remote deserted places which require transportation and placement of the heavy pipes under the ground and similarly like power lines the ski lift also undergo many complex constructions by transporting high rise poles to the mountains and placing them in erect positions and then extending lift cables throughout the poles. The high stability and high lifting capacity has made a great demand of Kaman K-max in the construction industry.

## V. CONCLUSION

We have come to know so far that Kaman K-max with intermeshing rotors have eliminated the need of tail rotor system and control the yawing moment by varying the blade pitch at one of the blades, which made the engine power supply to be directly given to the main rotors hence increasing its capacity of carrying external loads and its design of highly reinforced airframe enables it to repeatedly carry out lifting operations even for longer durations of time. Its enhanced technology and inculcation VRF (Vertical Reference Flight) and providing a greater field of view to the pilot has proved it to be an asset for rescue, defense, warfare, constructions and plethora of other operations. Despite of such features the helicopters with intermeshing rotors are rare. This is because of the fact that these helicopters have forward airspeed much slower as compared to other helicopter counterparts and this has reduced its popularity in the manufacturers and air market. Inculcating an electrical pusher motor at the rear of the helicopter may overcome this problem of lesser forward speed and along with its previously mentioned features might help it to regain its worth in the market. The noise level for these helicopters as already mentioned is very low as the sound of and alarm clock placed at a distance of 2ft. If electrical motors are used for both the main rotors and the pusher motor it can lead to further cut off the vibrations and already feeble noise of these helicopters. NASA is also undertaking a research to launch urban air-taxi with intermeshing rotors in the coming future because their main interest is not in high airspeed but in its combined benefits of high lift and least noise. Also, more advancement are being made by the Kaman Aerospace Corporation to enhance Kaman K-max unmanned version with sensor based autonomy and ground based operation set-ups, which will reduce casualties in the battlefields. However its low popularity today if researches are made to improve its features further than it will outperform every other helicopter in its league and will prove to be an asset to the owner by being one of most hard working and most efficient aircraft available in market.

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