



## METAL PROPELLER REPAIR MANUAL

### INTRODUCTION

The purpose of this Service Manual is to provide the repair information necessary to maintain a fixed-pitch metal propeller in an airworthy condition.

The types of service-damage which may render a fixed-pitch metal propeller unairworthy are mainly mechanical injuries such as cuts, nicks, and dents caused by the impact of stones, gravel, sand, etc. Usually a displacement of the metal is involved and the void is roughly V-shaped in cross-section with the sharp point of the "V" pointing inward, away from the surface of the metal. There is also a type of chemical damage which involves corrosion at the interfaces of the grain structure of the metal. In this manual it is called corrosion pitting. The mechanical effect of this on the strength of the metal is like that of a "V" notch with the sharpest possible edge. It is the objective of all repair techniques to remove this V-shaped notch and to leave the repaired area in a smooth, rounded, well-faired condition. It is worthwhile to understand the reasons behind these procedures.

A metal propeller is subjected to two kinds of loads or stresses. A stress is merely the load or force which acts across a unit area of the blade cross-section. The first of these stresses is steady and continuous and due to the combination of the centrifugal forces associated with the rotation of the propeller, and forces which are the reaction of the airload on the blade. These centrifugal forces are very large when a typical light-plane propeller is operating at its rated rotational speed. A slice of metal near the tip of the blade may exert an upward pull roughly 7500 times greater than its own weight. The forces due to the reaction of the blade to the airload tend to bend it out of the plane of rotation and the centrifugal forces tend to straighten the blade and bring it back into the plane of rotation, so that in operation the blade will seek some intermediate or equilibrium position. The sum of the stresses caused by these steady forces constitutes the total steady stress to which a blade is subjected at a given rotational speed, power input, and forward speed of the propeller. It varies, of course, along the radius of the blade in a manner which is determined by the shape of the blade. At rated conditions of power, rotational speed, and forward speed, it is possible, by proper design of the blade, to hold the maximum value of these steady stresses below a value of about 7500 pounds per square inch. This is about one-fourth of the yield strength of aluminum alloy 2025, heat-treated to Specification T6, which is the metal universally used throughout the light-plane propeller industry.

The second type of stress is an alternating or vibratory stress. In this type of stress, the blade is subjected other-

notely to loads which tend to stretch the metal and then to compress it. The sequence of events which occur as the load on a portion of the blade section varies from the point of maximum tension thru maximum compression and back to maximum tension is called a cycle of vibration. The time which elapses during a cycle is called the period of vibration. The number of cycles per second, or other unit of time, is called the frequency of the vibration. The number of cycles per revolution of the propeller is called the order of the vibration.

The forces which shake a propeller and cause it to vibrate arise mainly in the piston engine which drives it. A piston engine does not produce a smooth and constant torque. The rated torque of a direct-drive engine is merely the mean value of the torque impulses taken over a period of one revolution of the crankshaft. The orders of the torque impulses are determined by the number of engine cylinders and their arrangement. These orders are usually integer multiples of the number of firing impulses per revolution of the engine crankshaft. For example, a four-cylinder engine, with the cylinders in two banks, arranged at an angle of 180° to each other, will produce torque impulses at frequencies which are 2, 4, 6, 8, ... times the rotational speed of the engine.

A metal propeller, like a tuning fork, has a set of natural frequencies of vibration. These frequencies are determined by the shape of the blade—its length, thickness distribution, and width distribution. When one of the natural frequencies of the propeller coincides with the frequency of a shaking force put out by the engine, a resonance peak occurs. At this condition, depending upon the magnitude of the shaking forces coming from the engine and the damping forces in the propeller, vibratory stresses may become very large. During the design of a metal propeller intended for use on engines of a particular model, an effort is made to tune the propeller so that dangerous resonance peaks will fall outside the operating range of engine rotational speed.

Over the period of many years in which forged aluminum alloy propellers have been in use, service records have shown that a propeller can operate safely, provided the values of steady stress and vibratory stress are held to certain well-established levels. When a combination of steady and vibratory stresses is allowed to exceed these levels, after the accumulation of a sufficient number of vibration cycles, or fatigue cycles as we may call them, the strength of the metal begins to deteriorate and a fatigue crack may develop which can quickly lead to a failure of the propeller. Much test work has been done to determine the number of fatigue cycles required, of a

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