# HYDRAULIC REMOVAL OF COUPLING HUBS—KEYED AND KEYLESS

by

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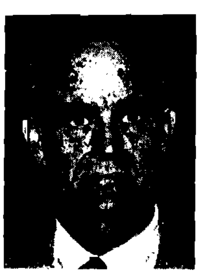
*Mr. Calistrat received his M.S. degree in Mechanical Engineering from the University of Bucharest and holds 17 patents.*



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## ABSTRACT

In rotating machinery, torque is transmitted from shafts to coupling hubs (or vice versa) through keys, friction, or a combination of the two. As a rule, coupling hubs must be installed on shafts with a certain amount of interference. This interference has two purposes: to prevent rocking of the hub on the shaft, and to help in the torque transmission. With sufficient interference all the torque can be transmitted by friction, and keys can be eliminated.

Interference has two disadvantages: it makes installation difficult, and hub removal even more difficult. Hydraulic methods of hub removal are discussed. These methods are sound, make for easy and quick hub removal, and are safe.

Some engineers are reluctant to use hydraulic removal for two reasons: it requires specialized tools and better training of mechanics, and it was known to be potentially dangerous. As any new and sophisticated procedure, it also received a bad name from early failures, all caused by misuse.

The following topics are discussed:

- Torque transmission through keys
- Installation of keyed hubs using interference
- Torque transmission through friction
- Installation of keyless hubs, heat-assisted installation, hydraulic assisted installation
- Hydraulic removal of hubs, dismounting keyed hubs, dismounting keyless hubs
- Failure cases

Hydraulic methods for hub removal were discussed in previous papers [1, 2]. The purpose herein is to compile and update previous information, and to describe good practices.

## TORQUE TRANSMISSION THROUGH KEYS

Keys are such an old machine part that the authors could not trace their origin. There are many shapes of keys, and all are standardized. Ultimately, all keys transmit torque through shearing of a rectangular cross section. Three completely different shapes of keys are shown in Figure 1, all having the same shearing section: a rectangle of width, W, and a length, $L_k$.

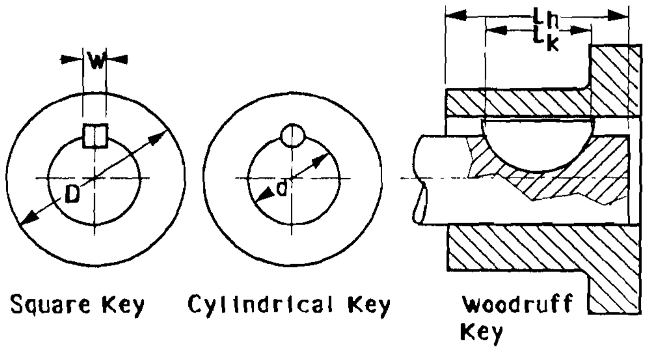


*Figure 1. Three Types of Shaft Keys. Note: The basic dimensions (width and length) remain the same for all types.*

Key dimensions were standardized about 150 years ago: the width to be 1/4 of shaft diameter, and the length to be 1.5 times shaft diameter. A simple shear stress calculation will demonstrate why these particular dimensions were chosen.

The shear stress generated by torque in a cylindrical shaft is:

$$\tau_s = \frac{2 \bullet T}{\pi \bullet r^3} = \frac{5.3 \times T}{d^3}$$

where
d = shaft diameter
T = torque
Note: if d is in in, and T in in/lb, $\tau$ is lb/in$^2$.
The shear stress generated by torque in the rectangular cross section of the key is:

$$\tau_k = \frac{2 \bullet T}{d \bullet W \bullet L_k}$$

Introducing the standardized key dimensions (W = d/4 and L = 1.5 d) the following is obtained:

$$\tau_k = \frac{5.1 \times T}{d^3}$$

It can be seen that the shear stresses in the shaft and in the key are practically identical; it goes without saying that the strength of the two materials must also be the same. Amazingly, this simple rule was forgotten over the years; today, almost all engineering handbooks include table after table of various key dimensions, but not a word about key material.

The authors have seen a number of costly machine failures that were caused by the use of low carbon steel keys in applications were both shafts and hubs were made of heat-treated alloy steels. An important rule to remember is that *the key material, and the key hardness, should be similar to that of the shaft or hub.*

## INSTALLATION OF KEYED HUBS USING INTERFERENCE

All couplings resist being misaligned; misalignment causes all types of couplings to tend to rock on their shafts. The back-and-forth motions of small amplitude and high frequency cause fretting wear to occur on bore and shaft surfaces; fretting induces fatigue in shafts, with catastrophic consequences, as shown in Figure 2.

*Figure 2. Fretting-Induced Shaft Failure. Note: Fretting was caused by the rocking of the hub on its shaft, motion possible because of installation without sufficient interference.*

The only way to avoid fretting is to use interference at installation. Interference is created when the bore diameter is slightly smaller that the shaft diameter. How much interference is required for preventing fretting occurrence? First define interference:

*Interference is the difference between the bore and shaft diameters, divided by the shaft diameter.* Therefore, interference is dimensionless: it is customary to refer to it as in/in, or mm/mm.

*Example A:*

A cylindrical shaft has a diameter of 4.000 in, and its hub bore has a diameter of 3.996 in. The resulting interference is.

$$i = \frac{4.000 - 3.996}{4.000} = 0.001$$

*Example B:*

A tapered shaft has a nominal diameter of 3.000 in, and a taper of 3/4 in/ft. The hub bore large end has a diameter of 2.995 in. At installation, the hub is advanced (drawn) on the shaft 0.048 in. The resulting interference is:

$$i = \frac{\text{taper} \times \text{advance}}{\text{shaft diameter}} = \frac{0.75}{12} \times 0.048 \times \frac{1}{3.000} = 0.001$$

Note that the bore diameter does not enter in the calculations; however, it must be smaller than the shaft by at least:

$$i \times d = 0.001 \times 3.000 = 0.003 \text{ in}$$

Going back to the question of how much interference is required to prevent fretting: experience has shown that a minimum of 0.0005 (in per in) at operating conditions will prevent the occurrence of fretting. Rotating speed creates centrifugal acceleration, which in turn causes the hub bore to grow. To ensure the minimum interference at operating speed, the authors recommend that: