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Paper machine reel-spool journals: guidelines for crack testing and repair or replacement

1. Scope

This document was created by a TAPPI Task Group to provide information and guidelines for nondestructive testing (NDT) of reel-spool journals used in paper mills. The document describes reel-spool design concepts, failures, inspection, and considerations for repair/replacement.

Reel-spool journal failures are a continuing concern in paper mills. Reel spools experience high rotational speeds, brake torque reaction stresses and are subject to impact loads from rough treatment on stands and rails. Failures are infrequent but consequences can include worker injury and severe damage to surrounding equipment. Mills should employ preventive maintenance practices to keep their reel spools in safe operating condition. The information in this document helps a mill inspect reel spools for fatigue cracking, the main damage mechanism.

Information provided in this document on journal materials, failure locations and mechanisms, recommended inspection frequency, nondestructive testing (NDT) methods and techniques, etc., generally applies to reel-spool journals of all sizes. The general concepts also are applicable to other journals and shafts.

2. Safety precautions

Care should be exercised when working with reel-spools to ensure they are properly supported/secured. Precautions are required to avoid unsafe situations where a worker could be struck or be trapped by a paper roll, caught in a pinch point or injured by other equipment. Personal protective equipment should be worn and safety rules obeyed when working in or around the paper machine, re-reeler or around rotating equipment, especially when rolls are lifted and moved. Mill hazard and safety requirements must be reviewed before any work is performed and followed at all times. If any loads are applied to the reel-spool as part of the testing, appropriately sized equipment should be used to apply these loads and procedures used to ensure the reel-spool is stable under all conditions.

This TIP may require the use of chemicals that may present a health hazard to workers. Procedures for handling such substances are set forth in Material Safety Data Sheets (MSDS) for those chemicals. Prior to the use of this technical information paper, the user should determine whether any of the chemicals to be used or disposed are potentially hazardous, and if so, strictly follow the procedures specified by both the manufacturer as well as the local, state and federal authorities to insure safe use and disposal of these materials.

3. Design and material selection

Background

Reel-spool journals' design, shock loading, and rotating operation makes them prone to mechanical fatigue. The stress magnitude and cumulative number of stress cycles affect fatigue life: higher stress and more frequent shock loading decrease fatigue life. Properly designed and manufactured reel-spool journals operate for decades provided abuse and damage are minimized, making reel-spool journal failures infrequent. Fatigue cracking is more likely if the reel spool journal is overloaded, bent, has excessive surface roughness and sharp corner radii, and if the bearing fails. Repairs, especially welding repairs, are a prominent cause of journal fatigue failure.

The number of cycles a reel-spool accumulates in a year depends on its service duty: many paper mills rotate reel-spools in and out of service on a regular basis to spread the usage over all the journals.

The reel-spool journal diameter changes along the journal length to keep local stresses relatively uniform. Journal diameters typically range from 3 to 12 in. (7.6 to 30.5 cm) over lengths ranging from 1 to 2 m (3 – 6 ft), depending on spool sizes and the drive and bearing arrangement. The journal can be shrunk-fit into the spool head or it can be an integral part of the head or the reel-spool body. Figure 1 shows a typical reel spool journal with a drive connection on the end and a rail “wheel/tire”.

Materials

Fatigue strength correlates positively with tensile strength up to certain limits. Most reel-spool journals are made from high strength, quenched-and-tempered carbon steels. Common materials are AISI 1045 or low alloy AISI 4140 or 4340 steel, typically hardened to 210 - 240 BHN, with tensile strength around 760 MPa (110 ksi).



Figure 1. Typical reel spool journal, with size steps, drive connection (only on driven ends) and rail “tire.”

4. Cracking mechanism and locations

Most cracks initiate on the surface of the journal at local macro stress-concentrators like the bottom corner for a diameter change step, keyway or hole. Local stress may be microscopically concentrated by a sharp radius, mechanical damage, machining marks or scores in the macro stress concentrating feature.

The most common crack location is the step radius nearest the reel head. Journals also fail in other locations, including the diameter step closest to the drive/brake hub and at a keyway. Journal cracks outboard of the bearings generally are of lower concern than those between the bearings.

Fatigue cracks typically are straight, tight and perpendicular to the primary cyclic stress. A fatigue crack initiates on a microscopic scale at a flaw or other micro-stress concentrator; the crack grows in a brittle manner at a rate defined by the size of the load and load cycle frequency, until the remaining cross-section fails in a ductile manner due to overloading.

Increasing the weight of paper on the reels or speeding up a machine increase the probability of fatigue cracking in reel-spool journals. Journals that are bent, have pounded “brinelled” surfaces and machining grooves in step corners, and other harmful surface conditions are more likely to have fatigue cracks.

5. Crack testing procedures

Test locations

The crack-prone surface must be exposed for penetrant testing (PT) or magnetic particle testing (MT). “Volumetric” testing (NDT) with ultrasonic flaw detection testing (UT) or acoustic emission testing (AET) does not require exposure of the cracked surface but requires accessible surfaces for the probe/sensors.

Test frequency

The frequency of crack testing will vary as each mill and machine has different operation conditions. Factors affecting the inspection frequency include the journal’s (rotating) age, coarseness of the drive and braking methods, and loading/stress level on each journal as a fraction of its tensile strength. General recommended practice is to