

# Photography of Gear Failures

Robert Errichello

**P**hotography is an essential part of gear failure analysis. It not only provides a fast, convenient way to accurately document the appearance of gear failures, but also is an effective diagnostic tool because the magnification obtained through photographic enlargement and slide projection often discloses evidence that may have been missed if the gears were not photographed.

I am not a professional photographer, however, I find it necessary to do my own photography. It has only been by personally composing the photographs through the camera viewfinder that the photographs show the particular detail I wish to capture.

While there are a multitude of ways to obtain good photographs and a huge array of photographic equipment to choose from, what follows is a description of equipment and techniques that I use for field and studio photography of gear failures. It is a proven system that has the following features:

- All equipment is lightweight and readily portable (easily carried on board aircraft);
- All equipment is robust enough to withstand the rigors of harsh industrial environments;
- The technique is easily learned and can be relied on to produce good photographs consistently.

## The Basics

The equipment necessary for gear failure photography is not elaborate and is readily available at good cam-

era stores. It consists of the camera, lenses, and a tripod. The subject of what kind of lighting to use and when will be discussed later in the article.

**Camera.** Most of the features of newer, computerized cameras are not necessary or do not work well for photographing gears. I have found that auto-focus cameras are not suited to the macrophotography of gears because the light reflected from shiny surfaces of gear teeth tends to confuse the computer. Almost any manual, 35 mm single lens reflex (SLR) camera body with quality lenses can be used for photographing gears. I use a manual Pentax SP 1000, SLR camera body that is an early version of the Pentax K-1000.

**Tripod.** For overall photographs I prefer to rely on ambient lighting, which usually requires relatively long exposures. With macrophotography, the lens needs to be stopped down in order to maintain the depth of field, which also requires long exposures. Therefore, a good tripod is a necessity to avoid camera-shake.

I use a Benbo Trekker 35 tripod with a pan-ballhead. It is compact and weighs less than five pounds. It is unique because the legs can be positioned at any angle, and it features a special monorail that allows you to raise, lower, extend, retract, twist or angle the camera without changing the tripod position. The flexibility is especially important for macrophotography because the working distances between the camera, umbrella, lamp



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### Robert Errichello

is the principal in GEARTECH, a gear consulting firm and founder of GEARTECH Software, Inc., in Albany, CA. He is also a writer and instructor on gear design, analysis and application subjects. He is a member of ASME, AGMA, STLE, and a Registered Professional Engineer in the State of California.

and subject are small, and the camera is usually the easiest item to adjust. The tripod adjusts easily to uneven terrain because each leg can be individually adjusted. This feature is especially important for photographing gears on-site where there may be limited space and no flat surfaces.

**Lenses.** I find that three lenses are sufficient for most of my failure analysis work. I use a 55 mm normal lens for most of the overall photographs of large gears and gearboxes. When there is not enough room to back away from the subject to include everything in the photograph, I use a 35 mm wide-angle lens. For close-up photographs of individual gear teeth, I use a 90 mm macro lens.

**Macrolenses.** Macrolenses are optically corrected for shooting at close range. Fixed-focal-length macrolenses have the best image quality. Macro/zoom lenses can focus closer than fixed-focal-length lenses, but they are not specifically designed for close-up work, and their image quality is not as good.

Fixed-focal-length lenses vary from about 50 mm to 200 mm. Longer focal lengths allow extra working distance between the lens and the subject. I use a Tamron SP 90 mm f/2.5 macrolens. The 90 mm focal length gives a minimum working distance of about 215 mm from the end of the lens to the subject (about 125 mm with extension tube).

The degree of magnification with macrolenses is specified as a magnification ratio, which is the ratio between the size of the subject's image on film and its real size. Most macrolenses have a magnification ratio of 1:2, which gives a film image that is 1/2 the real size. With an extension tube, the magnification ratio is increased to 1:1, giving a film image the same size as the subject.

#### Lighting The Subject

Gear teeth are hard to photograph properly, especially if they are highly

polished, because light reflecting from shiny surfaces causes "hot spots" in the photograph that obliterate details. Camera-mounted flashguns are especially problematic because the light is reflected off shiny surfaces directly into the lens. Some improvement is obtained by using an extension cord and holding the flashgun to the side at an angle so that reflected light is directed away from the lens, but there is no sure way to know where to place the flashgun.

The basic problem with flashguns is that they emit a point source of very harsh light. Adding diffusers to the flash helps to soften the light, but the lighting is still too harsh because it originates from a single point. White cards can be used to bounce the light from the flashgun, which in effect increases the number of light sources, but the results are still unpredictable.

A ring flash is an improvement over a flashgun because it surrounds the lens with a ring of even light that is relatively soft. The ring flash eliminates hot spots in most cases, except for mirror-like subjects, such as bearing raceways.

The performance of a flash can be improved immensely by directing the light into an umbrella that reflects the light back to the subject. In effect, the source of the light is increased to the size of the umbrella, and the light is diffused and softened.

**Tungsten Lighting.** A major disadvantage of flash photography is that the lighting cannot be previewed by looking through the viewfinder. The solution is to eliminate the flash and substitute a tungsten lamp. With the light from the tungsten lamp reflected from an umbrella, the photograph can be composed through the viewfinder, and the photographer can see exactly what the photograph will show. Shadows are easily controlled by moving the umbrella or subject, and fill light can be added by using white cards. I find that the umbrella

and tungsten lamp eliminate hot spots by providing soft, even illumination that results in photographs that are realistic and pleasing. The only disadvantage of the tungsten lamp is that it is hot and can be uncomfortable at close working distances.

#### Overall Photography

For overall photos of the entire gearbox or other large equipment, I use a 55 mm normal lens or a 35 mm wide angle lens. I prefer to use ambient lighting where possible because it

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### Basic Equipment for Gear Failure Photography

What follows is a list of my "personal favorites" in terms of equipment. Other, comparable equipment is on the market, and readers are encouraged to look for that which works best for them.

- Camera — Pentax SP 1000, 35 mm SLR
- Tripod — Benbo Trekker 35 with pan-ballhead
- Normal lens — Takumar 55 mm
- Wide angle lens — Tamron 35 mm
- Macrolens — Tamron SP 90 mm f/2.5 with extension tube
- Tungsten lamp — Lowel Totalight, 1000 W
- Umbrella — Photek Goodlitter Stowaway
- Light stand — Photoflex Litestand
- Color slide film — Kodak Ektachrome 320T Professional, ISO 320
- Color print film — Fujicolor Reala, ISO 100
- Gray card — Kodak 8 x 10 in. gray card
- Color card — Jobo
- Filters — No. 80A and skylight. (A skylight filter is a clear glass cover you may wish to put over your lenses to prevent scratches on them. A new lens may cost upwards of \$100; a skylight filter costs less than \$10.)
- Ring flash — Sunpak auto DX 8R
- Flashgun — Vivitar 283 with SB-4 power supply and flash cord
- Cable release

allows composition of the photograph through the lens. Ambient lighting avoids problems associated with flash photography, such as "hot spots" or overly dark backgrounds. Many industrial sites have fluorescent lights which create problems for most color films. However, Fujicolor Reala film gives excellent color reproduction, even with fluorescent lighting. The film speed is ISO 100, which is relatively slow, and it requires long exposures and a tripod.

#### Flash Photography

Flash photography is necessary for stop-action photography, such as when photographing a gear hanging from a swaying hoist. It also works well for photographing the interior of a gearbox through the inspection port because the light bounces off the interior surfaces of the housing, providing soft lighting. I use a Vivatar 283 flashgun for photographing components that are not shiny.

Nevertheless, to avoid hot spots, it is best to use an extension cord and hold the flash somewhat above and to the side, at about a 45° angle to the film plane. The flash can be mounted on a bracket attached to the camera or held in one hand. I find it convenient to hold the flash in my left hand and press the back of my wrist against my left temple, while holding the camera with my right hand. This maintains a consistent flash-to-camera distance.

When photographing at close range, this technique works well: Set the lens for the distance you want and the required aperture. Look through the viewfinder and rock back and forth slightly to focus precisely; then trip the shutter just as the subject becomes sharp. For components that are shiny, such as polished gear teeth, it is best to use the ring flash rather than the flashgun in order to avoid hot spots.

**Ring Flash.** It may not be practical to use a tungsten light in cramped quarters, for photography through small inspection ports, or in areas

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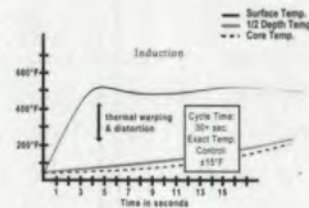
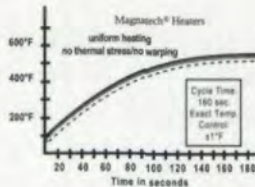
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where electric power is not available. For these cases I use a Sunpak ring flash with a battery pack. The ring flash surrounds the lens with light and produces soft illumination that avoids most "hot spots." The results are not as good as those achieved with the tungsten lamp because ring lighting lacks gives "flat" photos.

### Macrophotography

For most close-up photography, I use a macrolens and tungsten lighting. The advantages are:

- Tungsten lighting reflected from an umbrella gives soft, dispersed light that avoids "hot spots" or bright reflections from shiny gear teeth;
- Tungsten lighting allows viewing of the subject through the lens, enabling the photographer to see exactly what the photograph will show;

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### Macrophotography is a very effective tool for failure analysis.

• Adjusting the angle of the light, camera or subject allows the photographer to get just the right amount of shadow or highlights to enhance the features he or she wants to show.

I use a Lowel Tota-Light, 1000 W tungsten lamp for a light source and a Photek Goodliter Stowaway umbrella. The light and umbrella are mounted on a Photoflex Litestand. All the lighting equipment was chosen for its compactness. Total weight for the lamp, umbrella and stand is only six pounds.

For most of my photographs of gear teeth, I use the macrolens without the extension tube. A 4 x 6 in. print is about twice the real size of the subject. There have been several instances where the magnification

disclosed features that were not noted in visual inspection of the gears, proving that macrophotography is a very effective diagnostic tool for failure analysis.

For extreme close-ups, I add the extension tube to the macrolens. I reserve the extension tube for only those features of the subject that are especially interesting because it reduces the working distance and reduces the amount of light reaching the film. With less light, larger lens apertures are required, and there is less depth of field.

The major problems associated with macrophotography are:

- Working distances are small;
- Depth of field is shallow;
- Sharp focus is difficult to achieve.

### Films for Macrophotography

For color slides, I use Kodak Ektachrome 320T professional film. It is balanced for tungsten light, eliminating the need for a lens filter. If a daylight-balanced film is used in tungsten light, a No. 80A filter must be added to the camera lens to keep the pictures from being too orange. The disadvantages of using a No. 80A filter are that it:

- Requires two stops of exposure compensation, giving less depth of field for the same shutter speed;
- Gives a dim, blue image in the viewfinder;
- Gives the photographer one more thing to remember when changing films or light sources;
- Causes loss of image quality;
- Does not reproduce colors as well as a film originally balanced for tungsten light.

Unfortunately, I have not found a tungsten-balanced film for color prints, so I normally use daylight-balanced Fujicolor Reala with a No. 80A filter.

### Exposure

I use the camera's through-the-lens (TTL) meter and a gray card to get the proper exposure. For macrophotography with the tungsten light, a No. 80

A filter and Fujicolor Reala (ISO 100) film, the exposure is usually about f/11 with a shutter speed of one second. When using Kodak Ektachrome 320T slide film without the No. 80A filter, the exposure is usually about f/16 and 1/4 second.

I always bracket the exposures to ensure that I get at least one good photograph of each subject. For color print film, I bracket the base exposure by one stop. For example, if the base aperture is f/11, I also shoot the subject at f/16 and f/8. Because color slide film is more sensitive to the aperture setting, I bracket by 1/2 stop.

### Documentation

I start every roll of film by photographing a color card. I write the film roll number and the date on the color card. This permits me to identify any exposed roll of film because the first frame is the color card with the roll number and date. When the film is processed, I ask the photo laboratory to include a print of the color card. By comparing the actual color card to the laboratory's print of the color card, the laboratory can correct the processing so that it produces the correct colors.

I record each photograph on a log sheet and include a brief description of the subject and the aperture setting, shutter speed, type of film and lighting. The log sheet helps to identify the best camera settings for future photographs and correlates the photographs with my separate, written descriptions of gear failures.

It is a good idea to type a list of instructions for each photographic process when first beginning to do failure analysis photography. Put the instructions on a laminated card and keep it in your camera bag for quick reference. It is also a good idea to make a list of all your camera equipment and put it on a laminated card. When packing up your equipment at the end of the day, checking the list will avoid leaving equipment behind. ■