www.residualstress.org

Residual Stress

What are residual stresses

Residual stresses or locked-in stresses can be defined as those stresses existing within a body in the absence of external loading or thermal gradients. In other words residual stresses in a structural material or component are those stresses which exsist in the object without the application of any service or other external loads.

Factors that cause residual stresses

Residual stresses can be present in any mechanical structure because of many causes.
Residual stresses may be due to the technological process used to make the component.
Manufacturing processes are the most common causes of residul stress. Virtually all manufacturing and fabricating processes such as casting, welding, machining, molding, heat treatment, plastic deformation during bending, rolling or forging introduce residual stresses into the manufactured object. Residual stress could be caused by localized yielding of the material, because of a sharp notch or from certain surface treatments like shot peening or surface hardening.
Among the factors that are known to cause residual stresses are the development of deformation gradients in various sections of the piece by the development of thermal gradients, volumetric changes arising during solidification or from solid state transformations, and from differences in the coefficient of thermal expansion in pieces made from different materials.

Thermal residual stresses are primarily due to differential expansion when a metal is heated or cooled. The two factors that control this are thermal treatment (heating or cooling) and restraint. Both the thermal treatment and restraint of the component must be present to generate residual stresses.

When any object is formed through cold working, there is the possibility for the development of residual stresses.

A good common example of mechanically applied residual stresses is a bicycle wheel. A bicycle wheel is a very light and strong because of the way in which the components are stressed. The wire spokes are radial aligned and tightening the spokes creates tensile radial stresses. The spokes pull the rim inward, creating circumferential compression stresses in the rim. Conversely, the spokes pull the tubular hub outward. If the thin spokes were not under a proper tensile preload load the thin wire spokes could not adequately support the load of the rider.

What residual stresses can cause

Residual stresses can be sufficient to cause a metal part to suddenly split into two or more pieces after it has been resting on a table or floor without external load being applied.
Residual stresses can result in visible distortion of a component.
Residual stresses relaxation can deform a peace when it is in machining.

Role of residual stresses

Residual stresses have the same role in a structure’s strength as common mechanical stresses. However, while stress due to external loads can be calculated with a degree of accuracy, residual

stresses are difficult to foresee. It is, therefore, very important to have a reliable method able to measure them directly with minimum damage to the surface.
Residual stresses can play a significant role in explaining or preventing failure of a component at times. One example of residual stresses preventing failure is the shot peening of component to induce surface compressive stresses that improve the fatigue life of the component. Unfortunately, there are also processes or processing errors that can induce excessive tensile residual stresses in locations that might promote failure of a component.
It must be kept in mind that the internal stresses are balanced in a component. Tensile residual stresses are counter balanced by compressive residual stresses. Residual stresses are three-dimensional.

Residual stress measuring methods

x-ray diffraction
ultrasonic methods
magnetic methods
Electronic Speckle Pattern Interferometry
Hole drilling and strain gage technique
Core Hole drilling and strain gage technique

The hole drilling strain gage method

There are many situations where X-ray diffraction is not useful for measuring residual stresses. These include non-crystalline materials, large grained materials, nanomaterials, textured, or heavily deformed metals. In these cases, other mechanical methods such as the hole-drilling method is used. The hole-drilling method (ASTM Standard E837) relies on stress relaxation when a hole is drilled into the center of a rosette strain gage such as that shown below. When the material is removed by drilling, the extent of the strain relief is monitored by the gages and the direction and magnitude of the principal stresses can be calculated.

A special high speed air turbine drill (shown above) is used to first locate the drill to within 0.001"of the rosette center and then to remove material to a controlled depth. At each depth increment, the strain relief on each of the gages is measured and converted into stress. As subsequent material removals occur, the stress distribution as a function of depth can be estimated. The hole drilling method is used in those situations where the residual stress is relatively uniform over the drilling depth. Thus, it is not intended for situations where the residual stress is superficial.

The accuracy of the holedrilling method is directly related to the ability of locating the hole accurately in the center of the rosette. As an example, if the hole is no more than 0.001” off center, the residual strain error is less than 3%. In practice, the location accuracy is better than this, so the overall accuracy in residual stress measurements is quite good. Another important consideration in this method is the ability to drill the relief hole so as not to introduce new stresses. This is best achieved in hard materials by use of a high-speed turbine drill which avoids excessive rubbing of the cutting surface against the hole wall. As a result of careful design of the tool, the holes have flat bottoms and straight walls as required by ASTM E837. The hole drilling method has many advantages, but it also has many disadvantages. Of particolar concern is that the method is valid only up to about 50% of the yield strength of the test material. Thus, great care has to be exercised Rosette Gage (Magnification: 4x) when selecting testing methods

Hole drilling strain gage procedure

1.Install a special three to six strain gage rosette at the point where stresses are to be measured.
2.Wire the strain gages to a static strain indicator.
3.Attach and accurately position a drilling device over the target of the rosette.
4.Balance the gage circuits.
5.Drill hole in increments, being careful not to generate heat that would induce residual stresses.
6.Record strains after the strain indicator has stabilized.
7.Calculate stresses using strain data by means of formulas reported in ASTM E 837-08