PStress ®
Pulley Stress Analysis Software
Users Manual*

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*For PStress V3.5

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Symbols

σ_r	Stress in Radial Direction	(MPa)
σ_θ	Stress in Tangential Direction	(MPa)
σ_z	Stress in Axial Direction	(MPa)
τ	Shear Stress	(MPa)
S_u	Ultimate Tensile Strength	(MPa)
S_y	Yield Strength	(MPa)
S_e	Endurance Limit Strength	(MPa)

Chapter 1

Introduction

1.1 What is Pstress?

PStress is a proprietary program developed at CDI. The first version was created in 1984. This version used a closed-form analytical method to solve for the stresses in a pulley. The program was based on the work of H. Lange (1963) and W. Schmoltzi (1974). In 1993 CDI expanded the number of shapes PStress could model by added a relatively small number of finite elements to the pulley simulation. This allowed us to preserve the speed of the close-form analytical analysis, while adding the ability to model complex geometries. Xiangjun Qiu and Vinit Sethi published CDI's new simulation method (and comparisons between our method and full ANSYS simulations) in a paper titled *A New Pulley Stress Analysis Method Based on Modified Transfer Matrix.* This paper appeared in Bulk Solids Handling volume 13, issue 4.

PStress is a powerful tool that allows engineers to quickly predict the triaxial stress field in a pulley. Unlike a general purpose FEA program, different engineers using PStress will always get the same answer when simulating the same pulley geometry with the same appied loads. Meshing and boundary conditions are predetermined and most of the solution is analytical so computation times are typically less than one second. This allows designers to rapidly review the effect of a design change on the stress distribution in the pulley and quickly converge on an optimum pulley design.

1.2 Getting Started in PStress

The section contains instructions for verrifying that your copy of PStress is installed correctly by modelling a simple pulley. We begin by opening PStress and entering the dimensions of the pulley and shaft, as well as the forces on the pulley. Open PStress and enter the pulley properties exactly as they are shown in Figure 1.1.

> Note: The PStress input screen supports three languages– English, Spanish, and Portuguese. To change the default input screen language, select “Preferences” from the “Edit” menu. This will open the preferences dialog box which allows the user to set a default language.

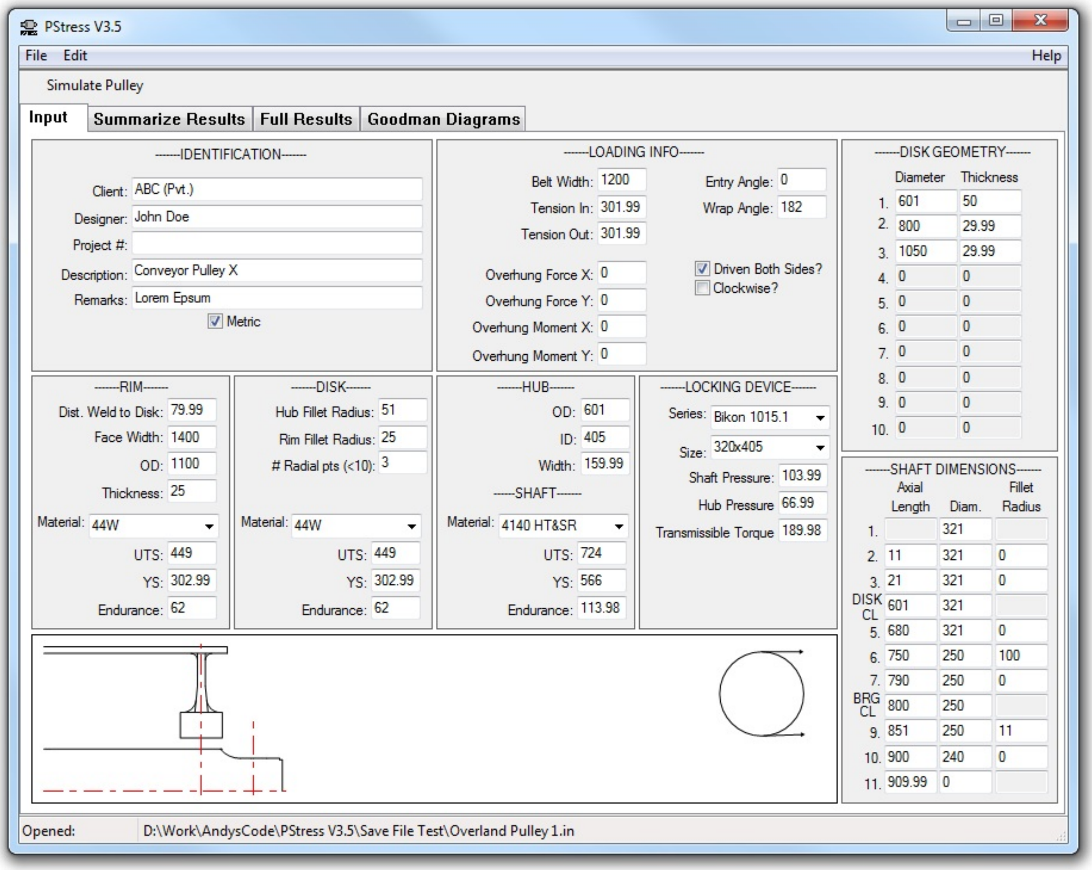

FIGURE 1.1: PStress Input Screen

After entering all the data shown in the Figure 1.1 save the file by selecting ”Save as” from the “File” menu. Once the file is saved click the “Simulate Pulley” button on the tool bar just below the file menu. This will run the PStress pulley solver. The solution will converge in less than a second. If everything is OK PStress will switch to the “Summarize Results” tab and the screen shown in Figure 1.2 will appear. If so, congratulations, your PStress installation was successful. Resave the file. This will tranfer the reports found in the Summarize Results and Full Results tabs to MS Word or MS Wordpad compatible reports in the same folder as the PStress input file.

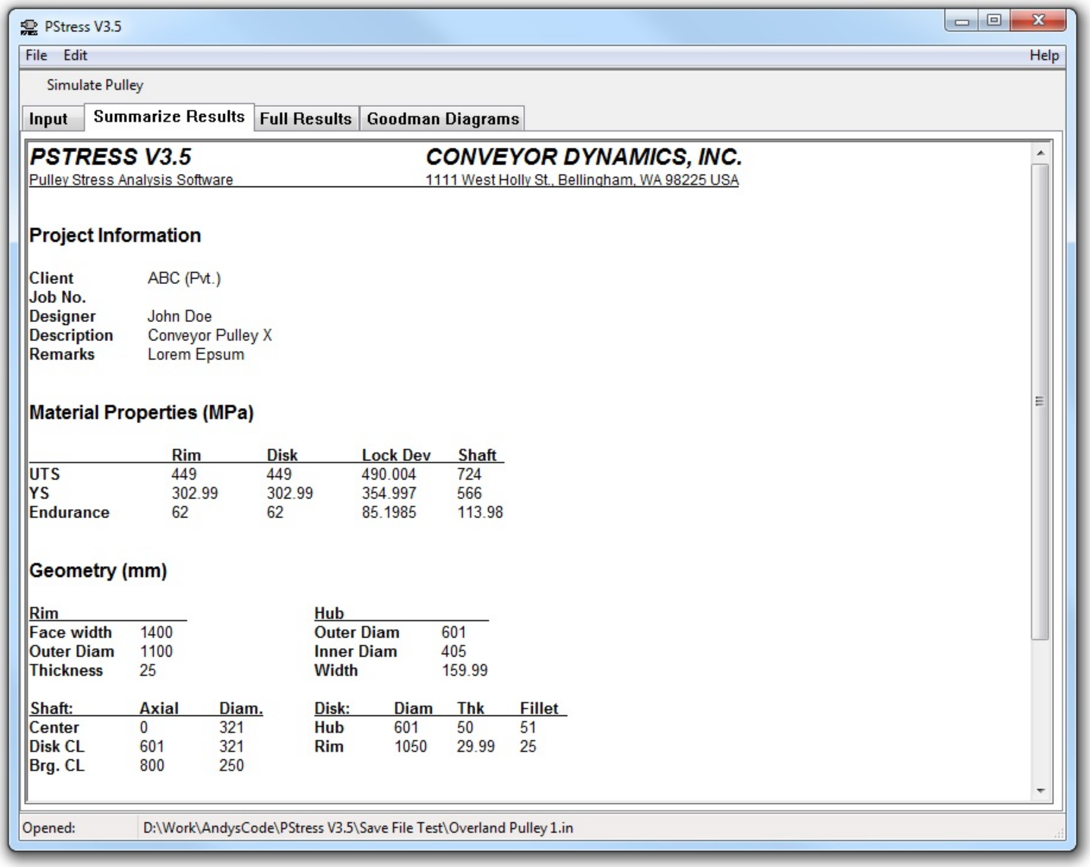

FIGURE 1.2: PStress Results Summary Screen

This concludes our brief overview of the PStress software. A deeper review of the input data required by and the output data produced by this software appears in successive chapters.

Chapter 2

Defining a Pulley in PStress

2.1 Pulley Shape

PStress is designed to compute the stresses in CEMA "Engineered Class" pulleys with T-Section end disks like the one shown in Figure 2.1

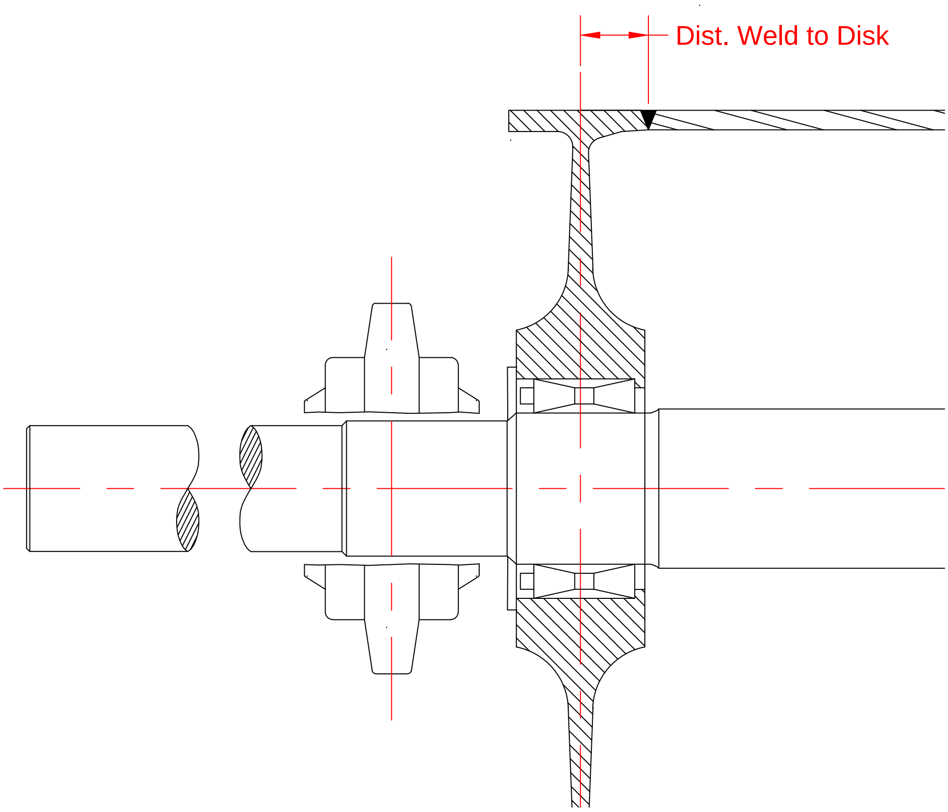

FIGURE 2.1: PStress Pulley Schematic

PStress assumes that the end disk is symmetrical. It also assumes that the fillet radii end tangent to the horizontal. If the fillet between the hub and the end disk is not tangent to the horizontal where the end disk meets the hub than the shape of the fillet will need to be manually defined using multiple points in the "Disk Geometry" section. PStress will interpolate between disk thickness values using a power function. *Note: to define multiple points in the "Disk Geometry" section the "# Radial pts (<10)" value must be incremented in the "Disk" section.*

2.2 Material Properties

The default materials known to PStress are listed in the *materials.txt* file found in the PStress installation folder. This file is a text file which the user can edit to add additional materials.

The Ultimate Tensile Stength and the Yield Strength of the materials in a pulley are usually easy to find. However, the endurance limit is not usually listed in suppliers tables. The PStress solver does not use endurance limit to compute the stresses in the pulley. However, this number is used by PStress to predict the onset of fatigue. CDI recommends using the following endurance limits, S_e, when evaluating pulleys:

Disk and Hub

The endurance limit strength is ±24% of yield strength in base metal and ±18% of yield strength in welded zones.

Rim

The endurance limit strength is ±15% of yield strength (note, there is a butt weld across the entire face of the pulley which will rotate through all high stress regions).

2.3 Locking Devices

The default locking devices included with PStress are found in the \Locking Devices\folder under the PStress installation folder (usually C:\Program Files\CDI\). \Locking Devices\contains a number of CSV (comma separated files) that define the locking devices available in PStress. Filenames define the values in the "Series" dropdown box in the Input tab. The contents of each file define the available sizes in each series. Addition locking device series can be added to PStress by simply placing additional CSV files in the Locking Devices folder. The names of the user added CSV files will automatically appear in the Series dropped control after PStress is restarted. The contents of the additional CSV file must be formatted identically to the contents of the existing CSV file. These file can be editted in a text editor like Notepad, or with MS Excel.

2.4 Shaft Geometry

The shape of the pulley shaft is defined by the table in the lower right hand corner of the "Input" tab. "Axial Length" is the distance from the center of the shell to the feature being defined. The 4th row of the table always specifies the location of the pulley end disk. The 8th row always specifies the location of the bearing. Turndown "fillet radius" end at the dimension specified in the axial length column. An illustration of the shaft dimension locations appears in Figure 2.2.

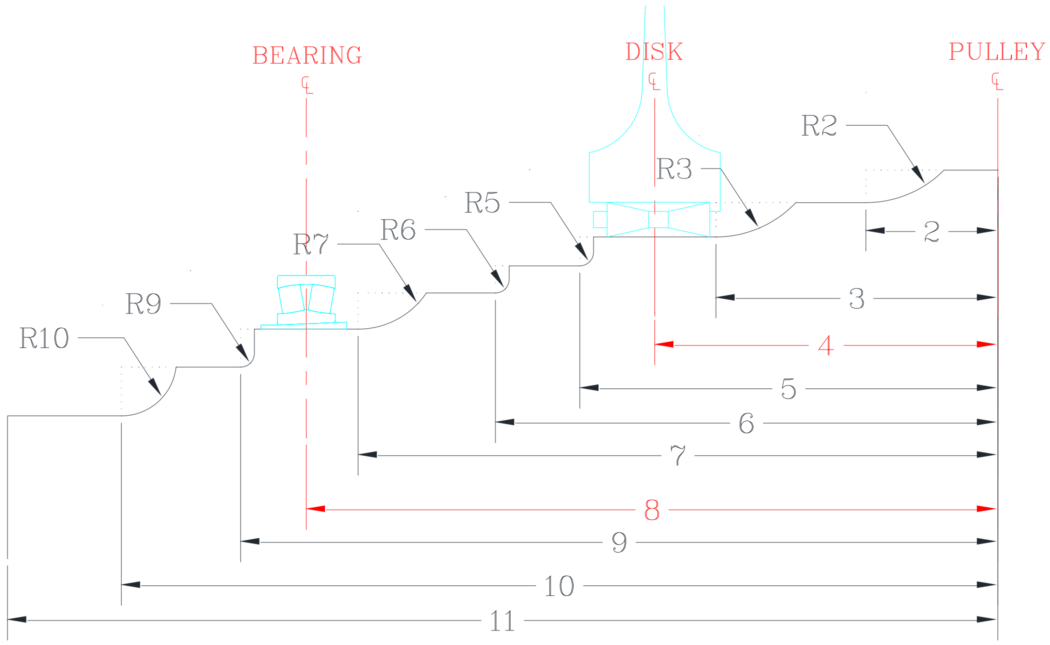

FIGURE 2.2: PStress Shaft Schematic

Chapter 3

Interpreting PStress Results

3.1 PStress Reports

The"Summarize Results" tab contains the minimum information needed to quickly determine if a pulley design is acceptable. It displays:

1. The material properties of the Rim, Disk, Locking Device, and Shaft
2. An overview of the dimensions of the Rim, Disk, Hub, and Shaft
3. A summary of the results including:
   (a) *Maximum Von Mises Stress* in the Rim, Disk, Hub, Locking Device, and Shaft.
   (b) *Yield Ratios* in the Rim, Disk, Hub, Locking Device, and Shaft. Note: the "Yield Ratio" is the ratio of the Max Von Mises Stress to the Yield Strength of the material.
   (c) *Fatigue Ratios* in the Rim, Disk, Hub, Locking Device, and Shaft. For the Rim, Disk, Hub and Locking device these ratios indicate how close a pulley component is fatigue failure according to the Goodman Fatigue Equation. The fatigue ratio for the shaft describes how close the shaft is to failure according to the Soderberg Fatigue Equation. A pulley is in danger of failing if any of these ratios is greater than 1.
   (d) *Bikon Slip Criteria.* This number indicates if the locking device pressure is high enough to prevent the locking element from slipping on the shaft. The value uses the "Transmissible Torque" field of the locking device definition to determine if the bending moment and shaft torque are in acceptable limits defined in Bikon's catalog. If this value is greater than 1, the locking device may slip.

The information provided in the Summarize Results tab is the minimum information required to evaluate a design. The report displayed in the full results tab provides substantially more information about the pulley to give the designer insight into why a particular pulley is failing. In addition to summarizing the materials used in the pulley and the pulley dimensions, the full results page shows the force on the bearings including the pulley weight, the relative stiffness of the various pulley components and tabulated stess distributions like those shown in Figure 3.1.

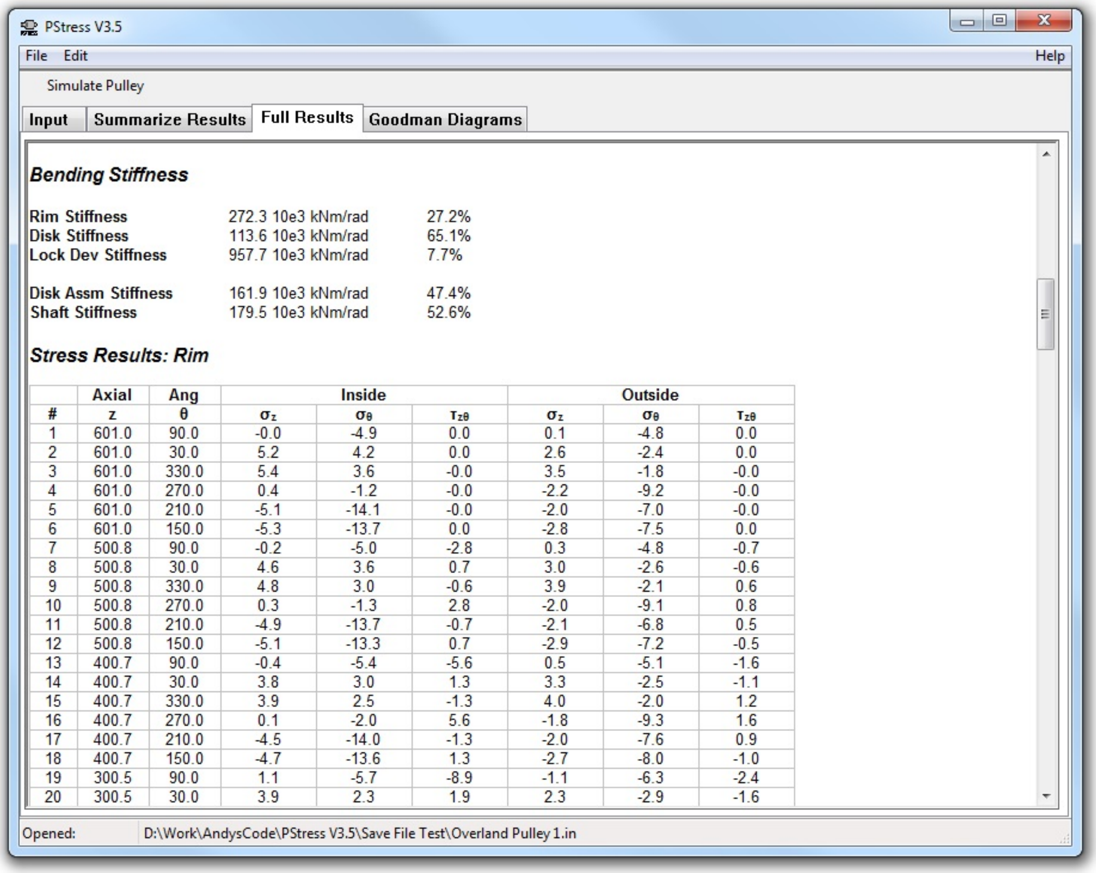

FIGURE 3.1: PStress Full Results

The stresses are tabulated for both sides of the pulley component surfaces. In PStress the "Inside" column refers to the interior of the pulley, and the "Outside" column refers to the exterior of the pulley. The following nomenclature is used in PStress's tables of stresses:

σ_R: Radial stresses

σ_θ: Tangential or hoop stresses

σ_z: Axial stress

$\tau_{R\theta}$: Shear stress (hub, disk, locking device)

$\tau_{Z\theta}$ Shear stress (rim)

In addition to the table of stresses, the reports also contain tabulated displacement tables for the rim, disk and shaft.

3.2 Fatigue Analysis using a Goodman Diagram

As the pulley rotates, the rim and the disk are subject to fluactuating stresses which can cause high-cycle fatigue failure in these parts. The Goodman diagram is used to determine is the various parts of the pulley will fatigue to failure. This diagram is shown in Figure 3.2. PStress will generate Goodman Diagrams for the rim, disk, hub, and locking device in the "Goodman Diagrams" tab of PStress. To use the Goodman diagram we define the following parameters:

$$\begin{aligned}
\sigma_{min} &= \text{minimum stress} \\
\sigma_{max} &= \text{maximum stress} \\
\sigma_a &= \text{stress amplitude} = (\sigma_{max} - \sigma_{min})/2 \\
\sigma_m &= \text{stress mean} = (\sigma_{max} + \sigma_{min})/2
\end{aligned}$$

The Goodman Diagram shows all the strengths and limiting values of the stress components for a particular mean stress. Failure is defined by the heavy outline. Goodman Diagrams generated by PStress can be copied to the clickboard by right-clicking them. After copying them to the clickboard, these diagrams can be pasted into MS Word or a similar program.

The *endurance limit strength*, S_e, is the point at which fatigue failure will not occur regardless of the number of cycles of loading applied to the part. The value of S_e is a function of material properties (discussed in the previous chapter), the manufacturing processes, the operating environment, and the design of the part.

In addition to the fatigue stress checks, CDI recommends adopting the following maximum stress limits:

Disk and Hub

The maximum combined stress should not exceed 70% of yield.

Rim

The maximum combined stress should not exceed 50% of yield.

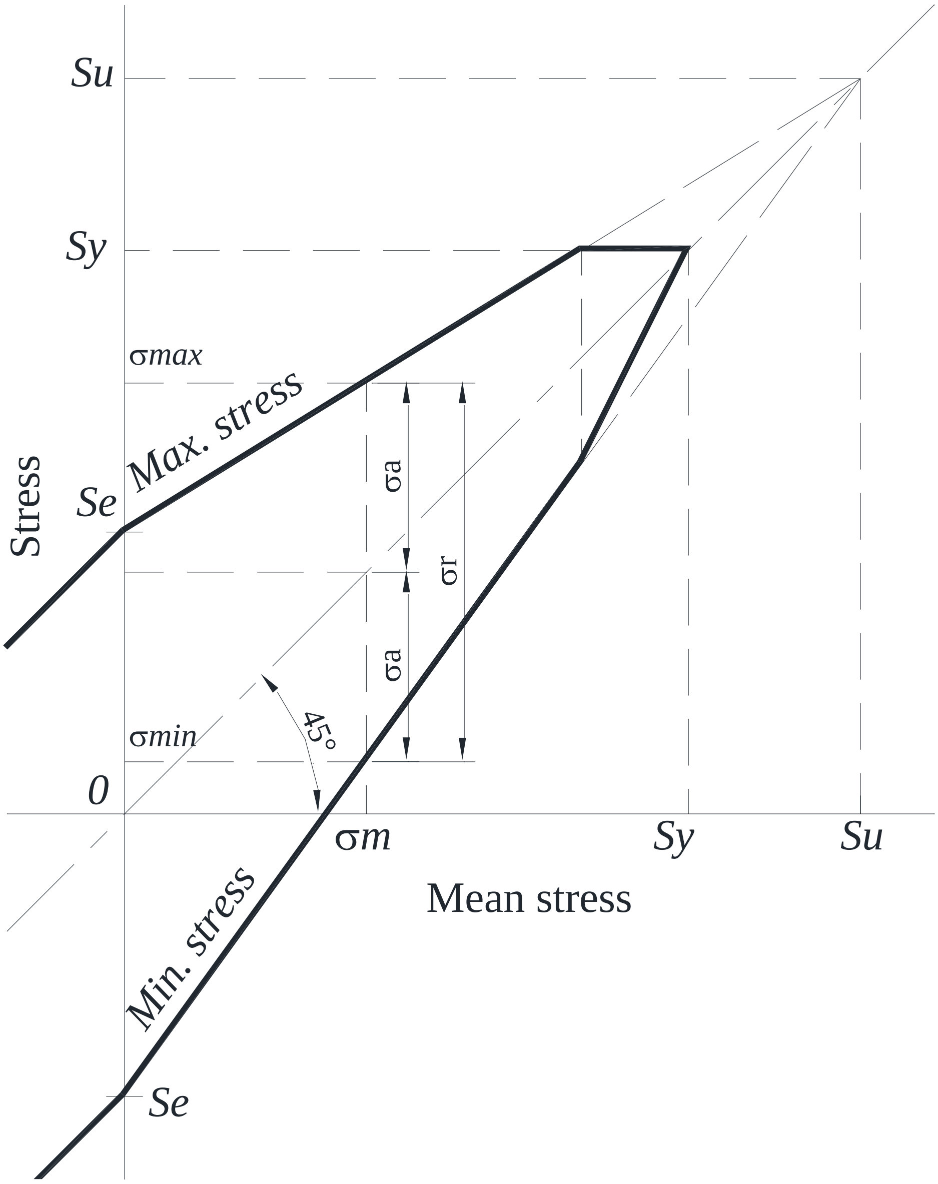

Figure 3.2: Goodman Diagram