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(JFCA)

**Weibull statistics of strength data  
for fine ceramics**

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## Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of Economy, Trade and Industry, through deliberations at the Japanese Industrial Standards Committee as the result of proposal of revision of Japanese Industrial Standard submitted by Japan Fine Ceramics Association (JFCA) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law applicable to the case of revision by the provision of Article 14.

Consequently **JIS R 1625**:1996 is replaced with this Standard.

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# Weibull statistics of strength data for fine ceramics

## Introduction

This Japanese Industrial Standard has been prepared based on the first edition of **ISO 20501** published in 2003, modifying some of its technical contents to correspond to the single mode and two population parameter Weibull statistics.

The portions with continuous sidelines or dotted underlines are the matters in which the contents of the corresponding International Standard have been modified. A list of modifications with the explanations is given in Annex JA.

## 1 Scope

This Standard specifies the single mode and two population parameter Weibull statistics which is a method for determining the shape parameter (Weibull coefficient) and scale parameter of the instant break strength data obtained from the bending strength test and tensile strength test of fine ceramics at room temperature and elevated temperature.

NOTE : The International Standard corresponding to this Standard and the symbol of degree of correspondence are as follows.

ISO 20501:2003 *Fine ceramics (advanced ceramics, advanced technical ceramics)—Weibull statistics for strength data* (MOD)

The symbols which denote the degree of correspondence in the contents in the corresponding International Standard and **JIS** are IDT (identical), MOD (modified) and NEQ (not equivalent) according to **ISO/IEC Guide 21-1**.

## 2 Normative references

The following standards contain provisions which, through reference in this Standard, constitute provisions of this Standard. The most recent editions (including amendments) of the standards indicated below shall be applied.

JIS R 1600 *Glossary of terms relating to fine ceramics*

JIS R 1601 *Testing method for flexural strength (modulus of rupture) of fine ceramics at room temperature*

JIS R 1604 *Testing method for flexural strength (modulus of rupture) of fine ceramics at elevated temperature*

JIS R 1606 *Testing methods for tensile strength of fine ceramics at room and elevated temperature*

JIS Z 8401 *Guide to the rounding of numbers*

## 3 Terms and definitions

For the purpose of this Standard, the terms and definitions in **JIS R 1600** and the following apply.

### 3.1 single mode Weibull distribution

a type of strength data group which is the subject of a statistical processing, involving single origin of failure and consisting of strength data of brittle fracture

### 3.2 shape parameter (Weibull coefficient: $m$ )

a parameter which determines the shape of probability density function in Weibull distribution and is an assessed value in practice

The larger this value is, the smaller the extension of strength distribution.

### 3.3 scale parameter ( $\beta$ )

strength at which the cumulative breaking probability becomes 63.2 % in two population parameter Weibull distribution and is an assessed value in practice

### 3.4 two population Weibull distribution

the Weibull distribution in which the location population parameter, out of three parameters: shape parameter, scale parameter and location population parameter, is zero

### 3.5 maximum likelihood method

a method to determine the population parameter in such a way that the probability of the obtained observation value being realized is the maximum

### 3.6 Weibull plot

to plot the strength data on Weibull probability paper graduated with the vertical axis  $\ln \ln(1-F)^{-1}$  and the horizontal axis  $\ln \sigma$ , where,  $F$  is the cumulative breaking probability and  $\sigma$  is the strength

### 3.7 ranking method of data

a method for calculating the cumulative breaking probability from an order number [6.2 e) 1)] of strength or breaking strength data

### 3.8 confidence interval

interval  $(\hat{\theta}_L, \hat{\theta}_U)$  in which the true value (population parameter)  $\theta$  of the parameter  $\hat{\theta}$  estimated from strength data is included with the predetermined fixed probability of not less than  $1-\alpha$ : where  $1-\alpha$  is confidence coefficient;  $\alpha$  is level of significance, for which, in this Standard, only 0.1 is used;  $\hat{\theta}_L$  and  $\hat{\theta}_U$  are lower confidence limit and upper confidence limit, respectively

## 4 Principle

In this Standard, the statistical data that clarifies the relation between the failure probability and the strength needed when using the immediate break strength data obtained from the bending strength test and tensile strength test of fine ceramics separately performed at room temperature and at high temperature, the strength of that material and its variation are compared with those of other materials, or the design of parts and materials is performed can be obtained. In order to make the applicability of statistical distribution strict, the strength test is limited to the bending and tensile test results in which the simple tensile stress field near the origin of failure is obtained,

and requires one kind of the source of failure. Although many original strength data are desirable for statistics, taking the variation of materials into consideration, “confidence interval” that refers to the likelihood of the obtained results can be also obtained. (Although, since it is statistics, the more original strength data are available, the better, the variation of materials should be taken into consideration, and the “confidence interval” representing the likelihood of the obtained results can also be determined.)

The strength data set is arranged in increasing order according to the procedure of this Standard, and the rank showing the order of the strength is calculated. Then, the shape parameter and scale parameter that express the characteristics of single mode Weibull distribution are obtained according to the iterative calculation method called maximum likelihood method. The confidence interval is calculated from the shape parameter, the scale parameter and the number of data obtained. For the results obtained, the relation between the strength and the failure probability is intelligibly shown by illustrating with numeric data.

## 5 Weibull distribution function used for statistical analysis

For the analysis of strength data, single mode and two population parameter Weibull distribution function, expressed by the following equation, shall be used.

$$F(\sigma) = 1 - \exp \left[ - \left( \frac{\sigma}{\beta} \right)^m \right]$$

where,  $F(\sigma)$ : single mode and two population parameter Weibull distribution function

$m$ : shape parameter

$\sigma$ : strength or breaking stress (Pa or N/mm<sup>2</sup>)

$\beta$ : scale parameter (Pa or N/mm<sup>2</sup>)

## 6 Statistical analysis method

### 6.1 Strength test data

The data to be the object for statistical analysis shall be bending strength test data and tensile strength test data, and their test methods shall, as a rule, be as follows.

- a) The bending strength test method shall be in accordance with **JIS R 1601** or **JIS R 1604**.
- b) The tensile strength test method shall be in accordance with **JIS R 1606**.
- c) Either of the strength tests shall use at least 30 test pieces.

### 6.2 Estimation of shape parameter and scale parameter

Obtain the shape parameter  $m$  and the scale parameter  $\beta$  which are the unknown population parameters of the Weibull distribution function, by means of the maximum likelihood method, and make the Weibull plot diagram.

The procedure shall be as follows.