

# Lower limb orthoses

## **Part 3. Method for the determination of mechanical properties of metal knee joint and side member assemblies**

Orthèses de membres inférieurs  
Partie 3. Méthode de détermination des  
propriétés mécaniques des articulations  
métalliques de genou et des pièces latérales

Orthosen für die unteren Gliedmasse  
Teil 3. Prüfung der mechanischen  
Eigenschaften von Kniegelenken aus Metall  
und Zubehör

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## Foreword

This Part of BS 2574 has been prepared under the direction of the Health Care Standards Policy Committee. It supersedes DD 157 : 1987 which is withdrawn.

DD 157 was prepared at the request of the Department of Health and Social Security to meet a need for a method of test to determine certain mechanical properties of metal knee joint and side member assemblies intended for use in the manufacture of lower limb orthoses. Details of methods of incorporation of joint assemblies into knee-ankle-foot orthoses are given in BS 2574 : Part 1 <sup>1)</sup>, and requirements for knee joint assemblies are given in BS 2574 : Part 2. Concern has been expressed regarding the hazards to the wearer of failure of a lower limb orthosis arising either from the imposition of loads experienced during normal use or from a sudden high load such as might be experienced from a fall. Two factors associated with the joint assembly are thought to be especially important, namely the strength to resist bending of the assembly, which determines the magnitude of the load necessary to induce failure, and the mode in which failure ultimately occurs.

The range of loads experienced in service by a lower limb orthosis has not yet been established. In addition, each orthosis is individually shaped and fabricated to the patient's needs, causing corresponding variations in induced stresses from any given loading.

Knee-ankle-foot orthoses may be subject in use to bending, torsion and axial loading but, because of the shaping of the joint and side members to accommodate the bulk of the patient's knee, the axial loading induces bending principally in the side members near the knee. Hence, bending is believed to be the major failure mechanism and so a test method has been evolved to determine the characteristics of joint assemblies in bending.

It is believed that the consequences of a sudden failure, in which the energy stored during elastic deformation of the joint assembly is rapidly released, are potentially more harmful than those of a ductile failure, in which plastic deformation of the joint assembly occurs. In the case of sudden failure there is a risk that the fractured parts may injure the leg of the wearer whereas should the joint assembly bend instead of break penetration of the leg is unlikely. Moreover, should the joint assembly fail during normal ambulation, a sudden failure is likely to cause the wearer to fall, whereas a ductile mode of failure may not totally deprive the wearer of support and the bending of the joint assembly may give warning of impending failure.

In addition, if a joint lock opens during ambulation the wearer may fall. Hence, if a lock is fitted, an assessment of the joint lock is included in the test procedure.

It is recognized that the mode of failure in service is dependent upon the design and fabrication of the joint and side member assembly as a whole. Sudden failure may occur due to:

- (a) failure of a brittle material used in the assembly;
- (b) failure of a joint component, such as a pin; or
- (c) malfunction of the locking mechanism.

To consider these features in more detail, a study was commissioned by the Department of Health and Social Security to develop a method of test to determine the mode of failure and hence to differentiate between those joint assemblies which could be expected to fail in a brittle manner and those that could fail in a ductile manner. This study resulted in the method of test given in DD 157, and which is established in this Part of BS 2574. In this test a pure bending moment is applied across the joint assembly by means of a four-point loading system.

In the conventional four-point bending test it is assumed that the deflections are

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<sup>1)</sup> In preparation.

small, enabling algebraic solutions in terms of the applied loads and test specimen geometry to be derived easily. However, in the event of large deflections of the magnitude expected during the testing of joint assemblies, the results can be assessed only by resolving the loads normal to, and along, the axis of the test specimen. To avoid this complexity, the conventional knife edge by which the load is transmitted to the specimen has been replaced by two pairs of rotating rollers. Simultaneous contra-rotation of each pair of rollers ensures that the applied loads are always normal to the test specimen.

This modified loading system allows the determination of mechanical properties of which the following are regarded as the most important:

- (1) the bending moment at the limit of proportionality (elastic deformation);
- (2) stiffness (elastic modulus);
- (3) maximum bending moment (ultimate strength);
- (4) ductility.

As the location and size of holes needed to secure the calf bands to the joint assembly are dependent on the patient's anatomy (or stature), these are usually drilled when fabricating each orthosis. Hence, in order to standardize the test procedure, it was decided that the test should be carried out on intact specimens (see note to clause 4).

The use of the method described in this Part of BS 2574 will enable relevant mechanical properties of knee joint assemblies, including the inherent variability of joint performance and the modes of failure, to be determined. This information will permit, at a future revision of BS 2574 : Part 2, the specification of criteria of acceptability for these assemblies.

Manufacturers of knee joint assemblies should be aware that product reliability is dependent upon the application of an appropriate quality system, and it is advisable to consider the desirability of assessment of the quality system against BS 5750 : Part 1.

**Compliance with a British Standard does not of itself confer immunity from legal obligations.**

# Method

## 1 Scope

This Part of BS 2574 describes a method of test for knee joint assemblies intended for use in the manufacture of lower limb orthoses. Procedures are described for determining the strength and ease of deformation, for establishing the mode of failure and for assessing the integrity of both the joint and lock mechanisms of metal knee joint and side member assemblies when loaded in bending. These test procedures are only suitable for joint assemblies (see 2.3) if the test rollers can be placed on parallel sections of the side members.

These test procedures are intended to assist in the selection of knee joint and side member assemblies, but are not intended for the testing of complete lower limb orthoses.

NOTE. The titles of the publications referred to are listed on the inside back cover.

## 2 Definitions

For the purposes of this Part of BS 2574 the following definitions apply, together with the definitions, other than those given below, in BS 2574 : Part 2.

### 2.1 knee joint<sup>1)</sup>

A joint in the side member of a lower limb orthosis that allows movement in the principal plane of flexion of the anatomical knee joint.

### 2.2 side member<sup>1)</sup>

A medial or lateral component of either one-piece or composite construction and including side pieces, end pieces, joints or adjustment devices.

### 2.3 joint assembly

A knee joint with integral side members or with side members attached.

### 2.4 parallel side member

A side member whose individual above-knee and below-knee components have cross sections of essentially constant dimensions.

### 2.5 stepped side member

A side member whose cross section, at a distance of more than 75 mm from either side of the axis of flexion, is reduced to a smaller cross section of constant dimensions.

### 2.6 elastic deformation

Deformation that diminishes to zero on removal of the load that caused it.

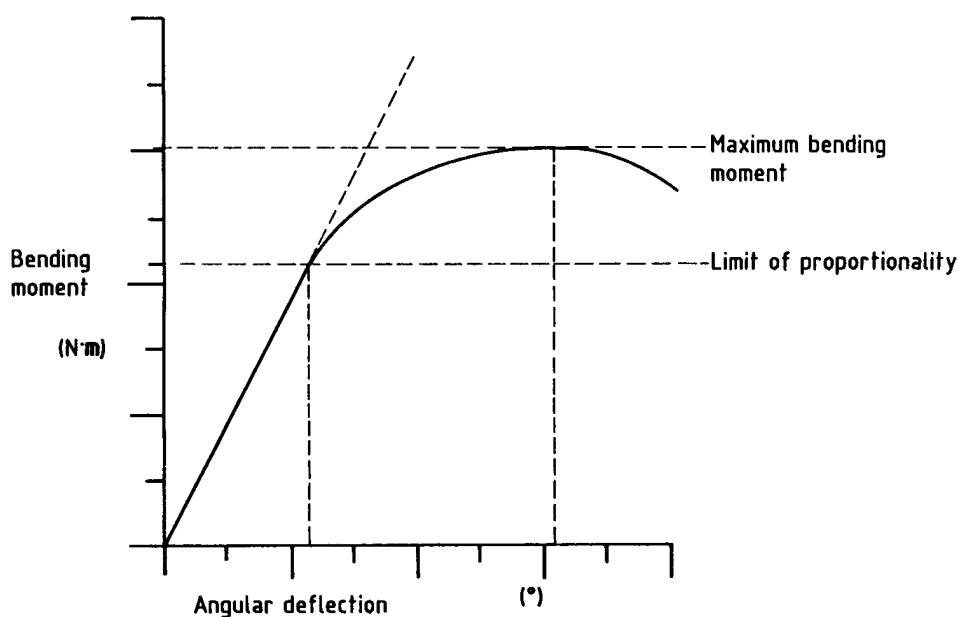


Figure 1. Example of a bending moment/angular deflection curve: single-stage failure (see 2.9)

<sup>1)</sup> Based on the definitions given in BS 2574 : Part 2.