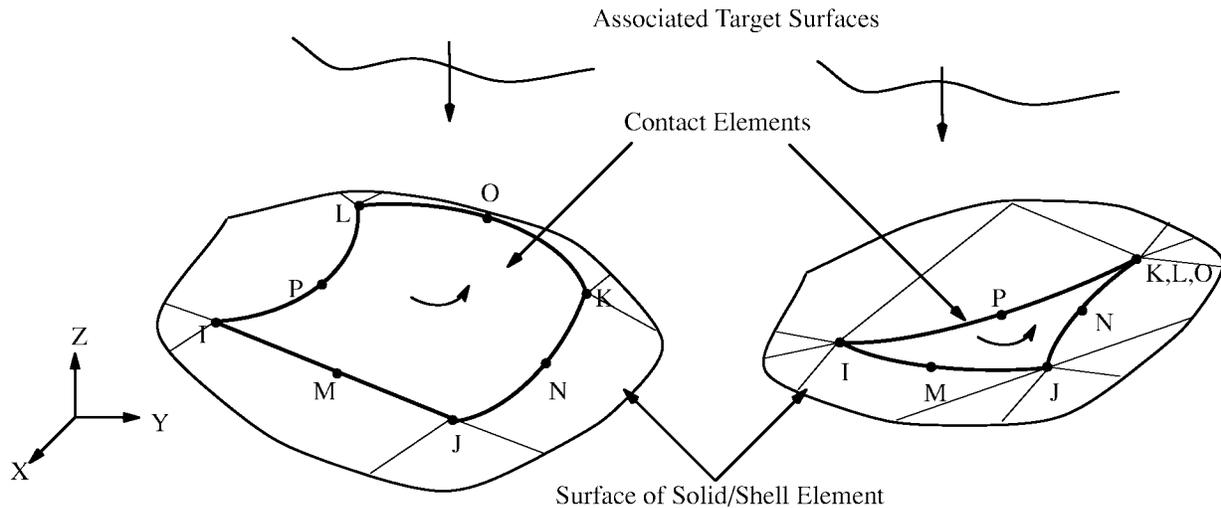


# 14.174 CONTA174 — 3-D 8-Node Surface-to-Surface Contact



Matrix or Vector	Geometry	Shape Functions	Integration Points
Stiffness Matrix and Stress Stiffness Matrix	Quad	If KEYOPT(4) = 0 (has midside nodes) equations (12.5.10-1), (12.5.10-2) and (12.5.10-3)	2 x 2
	Triangle	If KEYOPT(4) = 0 (has midside nodes) equations (12.5.5-1), (12.5.5-2) and (12.5.5-3)	3

## 14.174.1 Introduction

CONTA174 is an 8-node element that is intended for general rigid-flexible and flexible-flexible contact analysis. In a general contact analysis, the area of contact between two (or more) bodies is generally not known in advance. CONTA174 is applicable to 3-D geometries. It may be applied to contact of solid bodies, or shells, to static or dynamic analyses, to problems with or without friction.

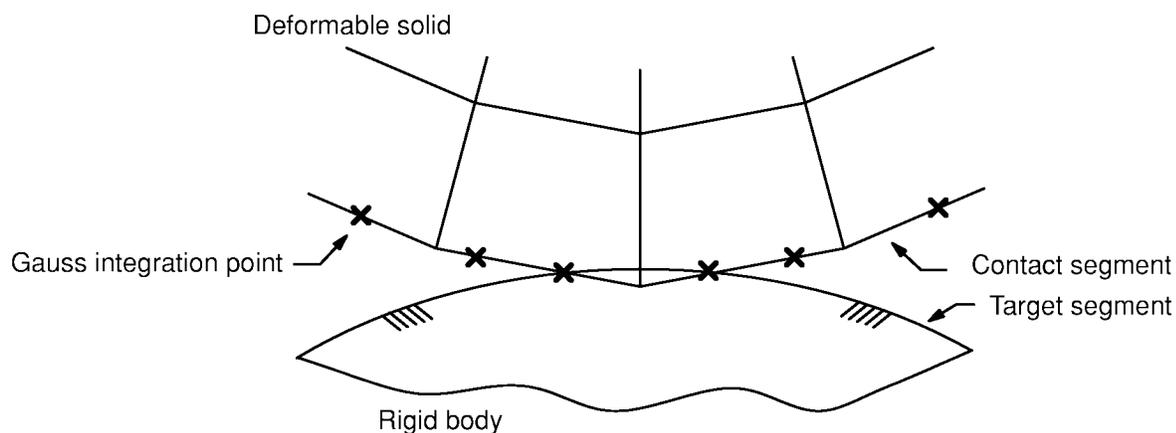
## 14.174.2 Contact Kinematics

### Contact Pair

In studying the contact between two bodies, the surface of one body is conventionally taken as a contact surface and the surface of the other body as a target surface. The “contact–target” pair concept has been widely used in finite element simulations. For rigid–flexible contact, the contact surface is associated with the deformable body; and the target surface must be the rigid surface. For flexible–flexible contact, both contact and target surfaces are associated with deformable bodies. The contact and target surfaces constitute a “Contact Pair”.

CONTA174 contact element is associated with the 3–D target segment elements (TARGE170) via a shared real contact set number. This element is located on the surface of 3–D solid, shell elements (called underlying element) without midside node. It has the same geometric characteristics as the underlying elements. The contact surface can be either/both side of the shell or beam elements.

### Location of Contact Detection



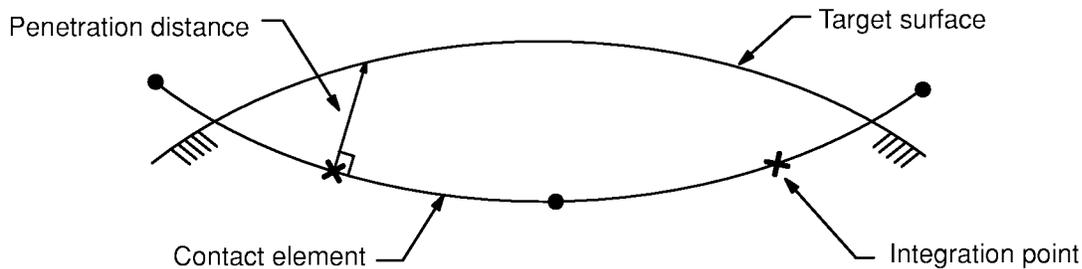
**Figure 14.174–1 Contact Detection Point Location at Gauss Point**

CONTA174 is surface–to–surface contact element. The contact detection points (i.e. the integration points) are located either at nodal points or Gauss points. The contact elements is constrained against penetration into target surface at its integration points. However, the target surface can, in principle, penetrate through into the contact surface. See Figure 14.174–1. CONTA174 uses Gauss integration points as a default (Cescotto and Charlier(213), Cescotto and Zhu(214)), which generally provides more accurate results than those using nodes themselves as the integration points. Also the contact node may slip off the edge of the rigid surface when contact detection points are located at nodal level. If this happens, the contact state will be lost and the

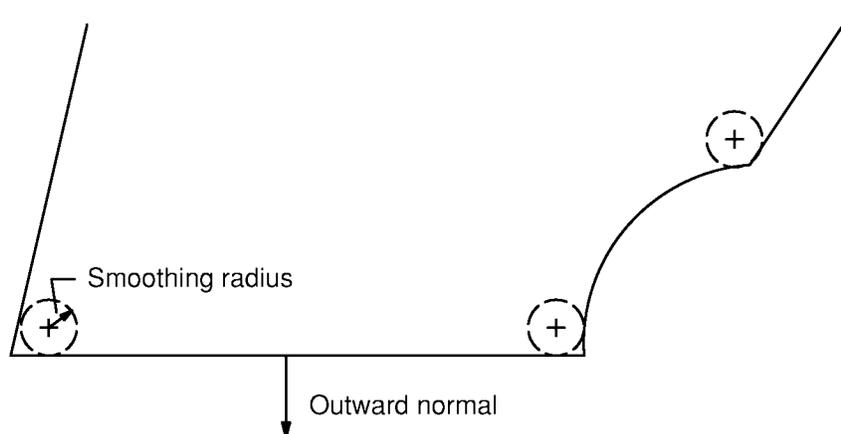
convergence difficulties will follow. Other disadvantage with the use of nodal contact points is that: when for a uniform pressure, the kinematically equivalent forces at the nodes are unrepresentative and indicate release at corners.

### **Penetration Distance**

The penetration distance is measured along the normal direction of contact surface located at integration points to the target surface (Cescotto and Charlier(214)). See Figure 14.174–2. It is uniquely defined even the geometry of the target surface is not smooth. Such discontinuities may be due to physical corners on the target surface, or may be introduced by a numerical discretization process (e.g. finite elements). Based on the present way of calculating penetration distance there are no restriction on the shape of the rigid target surface. Smoothing is not always necessary typically for the concave corner. For the convex corner, we still recommend the user to smooth out the region of abrupt curvature changes (see Figure 14.174–3).



**Figure 14.174–2 Penetration Distance**



**Figure 14.174–3 Smoothing Convex Corner**

### **Pinball Algorithm**

The position and the motion of a contact element relative to its associated target surface determines the contact element status. The program monitors each contact element and assigns a status:

STAT=0 Open far-field contact  
 STAT=1 Open near-field contact  
 STAT=2 Sliding contact  
 STAT=3 Sticking contact

A contact element is considered to be in near-field contact element enters a pinball region, which is centered on the integration point of the contact element. The computational cost of searching for contact depends on the size of the pinball region. Far-field contact element calculations are simple and add little computational demands. The near-field calculations (for contact elements that are nearly or actually in contact) are slower and more complex. The most complex calculations occur the elements are in actual contact.

Setting a proper pinball region is useful to overcome spurious contact definitions if the target surface has several convex regions. The current default setting should be appropriate for most contact problems.

## 14.174.3 Frictional Model

### Coulomb's Law

In the basic Coulomb friction model, two contacting surfaces can carry shear stresses up to a certain magnitude across their interface before they start sliding relative to each other. The state is known as sticking. The Coulomb friction model is defined as:

6/30/99    yyz        dv-5563        contact cohesion

$$\tau_{lim} = \mu P + b \quad (14.174-1)$$

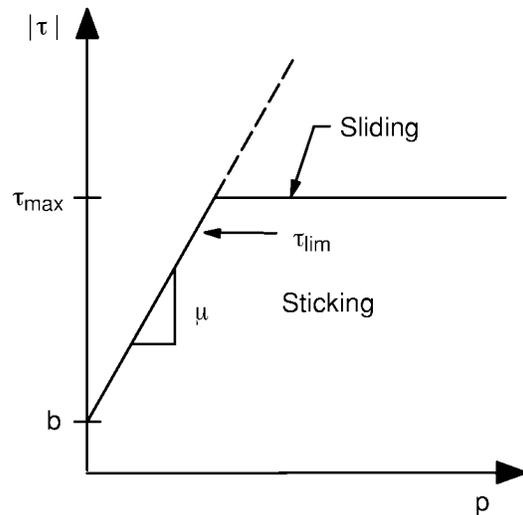
$$|\tau| \leq \tau_{lim} \quad (14.174-2)$$

where:

- $\tau_{lim}$  = limit shear stress
- $\tau$  = equivalent shear stress
- $\mu$  = frictional coefficient (input as MU on **MP** command)
- $P$  = contact normal pressure
- $b$  = contact cohesion (input as COHE on **R** command)

Once the equivalent shear stress exceeds  $\tau_{lim}$ , the contact and target surfaces will slide relative to each other. This state is known as sliding. The sticking/sliding calculations determine when a point transitions from sticking to sliding or vice versa. The contact cohesion provides sliding resistance even with zero normal pressure,

CONTA174 provides an option for defining a maximum equivalent shear stress  $\tau_{max}$  (input as TAUMAX on **RMORE** command) so that, regardless of the magnitude of the contact pressure, sliding will occur if the magnitude of the equivalent shear stress reaches this value. See Figure 14.174-4.



**Figure 14.174-4 Friction Model**

### **Integration of Frictional Law**

The integration of the frictional mode is similar to that of non-associated theory of plasticity (see Section 4.1). In each substep that sliding friction occurs, an elastic predictor is computed in contact traction space. The predictor is modified with a radial return mapping function, providing both a small elastic deformation along sliding response as developed by Giannakopoulos(135).

### **Algorithmic Symmetrization**

Contact problems involving friction produce non-symmetric stiffness. Using an unsymmetric solver is more computationally expensive than a symmetric solver for each iteration. For this reason, a symmetrization algorithm developed by Laursen and Simo(216) is used by which most frictional contact problems can be solved using solvers for symmetric systems. If frictional stresses have a substantial influence on the overall displacement field and the magnitude of the frictional stresses is highly solution dependent, any symmetric approximation to the stiffness matrix may provide a low rate of convergence. In such cases, we had to use unsymmetric stiffness to improve convergence.

## **14.174.4 Contact Algorithm**

For this surface-to-surface contact elements, either the augmented Lagrangian method (Simo and Laursen(215)) or the penalty method is used. The augmented Lagrangian method is an iterative series of penalty updates to find the exact Lagrange multipliers (.i.e. contact tractions). Compared to the penalty method, the augmented Lagrangian method usually leads to better conditioning and is less sensitive to the magnitude of contact penalty coefficient.