*IGA

The *IGA keywords set up and control the isogeometric-related capabilities of LS-DYNA. The *IGA keyword cards may be classified into two sets. Keywords included in the first set are used to describe basic geometric objects. Keywords in the second set are used to create isogeometric elements for the numerical model. In addition, keywords referenced and used in combination with the *IGA keywords are also listed. Keywords in each group are listed in alphabetical order.

Keywords to define geometry:

*IGA_1D_BREP

*IGA_1D_NURBS_UVW

*IGA_1D_NURBS_XYZ

*IGA_2D_BASIS_TRANSFORM_XYZ

*IGA_2D_BEZIER_XYZ

*IGA_2D_BREP

*IGA_2D_NURBS_UVW

*IGA_2D_NURBS_XYZ

*IGA_3D_BASIS_TRANSFORM_XYZ

*IGA_3D_BEZIER_XYZ

*IGA_3D_NURBS_XYZ

*IGA_EDGE_UVW

*IGA_EDGE_XYZ

*IGA_FACE_UVW

*IGA_FACE_XYZ

*IGA_INCLUDE_BEZIER (obsolete as of R14)

*IGA_POINT_UVW

*IGA_VOLUME_XYZ

*IGA

Keywords to create isogeometric elements:

*IGA_REFINE_SHELL

*IGA_REFINE_SOLID

*IGA_SHELL

*IGA_SOLID

Additional IGA-related keywords:

*IGA_INTEGRATION_SHELL_REDUCE

*IGA_INTEGRATION_SOLID_REDUCE

IGA_MASS_*OPTION

*IGA_TIED_EDGE_TO_EDGE

*SECTION_IGA_SHELL

*SECTION_IGA_SOLID

*SET_IGA_EDGE

*SET_IGA_FACE

*SET_IGA_POINT_UVW

*IGA_1D_BREP

Purpose: Define a one-dimensional boundary representation, that is, a closed loop, composed of parametric edges(s).

Card 1	1	2	3	4	5	6	7	8
Variable	BRID							
Type	I							
Default	none							

Parametric Edge Cards. Include as many cards in the following format as desired, see Remark 1. This input ends at the next keyword ("*") card.

Card 2	1	2	3	4	5	6	7	8
Variable	EID1	EID2	EID3	EID4	EID5	EID6	EID7	EID8
Type	I	I	I	I	I	I	I	I
Default	none	none	none	none	none	none	none	none

VARIABLE	DESCRIPTION
BRID	One-dimensional boundary representation ID. A unique number must be chosen.
EID*i*	Parametric edge IDs, see *IGA_EDGE_UVW.

Remarks:

1. **Parametric Edge Ordering.** Parametric edges listed on Card 2 need to be ordered such that they form a closed loop. That is, the start and end points of an arbitrary parametric edge should coincide with the end point of the previous and starting point of the next parametric edge, respectively. If the loop is comprised of a single parametric edge only, its start and end points should be identical.

*IGA_1D_NURBS_UVW

Purpose: Define a parametric univariate non-uniform rational B-spline (NURBS).

Card Summary:

Card 1. This card is required.

PATCHID	NR	PR					

Card 2. This card is required.

UNIR							

Card 3a. Include ceil[(NR + PR + 1)/4] of this card if UNIR = 0.

R1	R2	R3	R4

Card 3b. Include this card if UNIR ≠ 0.

RFIRST	RLAST		

Card 4. Include NR of this card.

U	V	W	WGT

Data Card Definitions:

Card 1	1	2	3	4	5	6	7	8
Variable	PATCHID	NR	PR					
Type	I	I	I					

VARIABLE	DESCRIPTION
PATCHID	Parametric univariate NURBS patch ID. A unique number must be chosen.
NR	Number of control points in the local r-direction
PR	Polynomial degree of the basis in the local r-direction

Card 2	1	2	3	4	5	6	7	8
Variable	UNIR							
Type	I							
Default	0							

VARIABLE	DESCRIPTION
UNIR	Knot vector type in the local r-direction: EQ.0: Specify the entire knot vector in the local r-direction EQ.1: Uniform open knot vector in the local r-direction EQ.2: Uniform periodic vector in the local r-direction

Knot Vector Cards for the r-direction. Include ceil[(NR + PR + 1)/4] cards if UNIR = 0.

Card 3a	1	2	3	4	5	6	7	8
Variable	R1		R2		R3		R4	
Type	F		F		F		F	

VARIABLE	DESCRIPTION
Ri	Knot values in the local r-direction with $i = 1, \ldots, \mathrm{NR} + \mathrm{PR} + 1$

Knot Vector Cards for the r-direction. Include this card if UNIR ≠ 0. See Remark 1.

Card 3b	1	2	3	4	5	6	7	8
Variable	RFIRST		RLAST					
Type	F		F					

VARIABLE	DESCRIPTION
RFIRST	First knot value in the local r-direction

VARIABLE	DESCRIPTION
RLAST	Last knot value in the local r-direction

Control Point and Weight Cards. Include NR cards; see Remark 2.

Card 4	1	2	3	4	5	6	7	8
Variable	U		V		W		WGT	
Type	F		F		F		F	
Default	none		none		none		1.0	

VARIABLE	DESCRIPTION
Uj	Nonhomogeneous control point coordinates in the parametric u-direction with $j = 1, \ldots,$ NR
Vj	Nonhomogeneous control point coordinates in the parametric v-direction with $j = 1, \ldots,$ NR
Wj	Nonhomogeneous control point coordinates in the parametric w-direction with $j = 1, \ldots,$ NR
WGTj	Control weights with $j = 1, \ldots,$ NR, see Remark 3.

Remarks:

1. **Uniform Knot Vectors.** RFIRST and RLAST define the interval for uniform knot spans. As an example suppose that NR = 4, PR = 3, RFIRST = 1, and RLAST = 8 which yields the following uniform open and uniform periodic vectors [1 1 1 1 8 8 8 8] and [1 2 3 4 5 6 7 8] for UNIR = 1 and UNIR = 2, respectively.

2. **Parametric Curve.** A parametric curve may be defined in the parametric space of an n-variate physical NURBS, such as *IGA_nD_NURBS_XYZ with $n = 2$ or 3, which requires the definition of (U, V) and (U, V, W) coordinates, respectively. Note that the parametric u-, v-, w-directions and (U, V, W) coordinates are equivalent to the local r-, s-, t-directions and (R, S, T) coordinates in the parametric space of the physical NURBS. This notation is adopted here only to distinguish between the parametric space of the parametric univariate NURBS and the parametric space of the physical bi- or trivariate NURBS in which it is embedded.

3. **Control Weights.** Control weights must be positive and will otherwise be reset to the default unit value.

*IGA_1D_NURBS_XYZ

Purpose: Define a physical univariate non-uniform rational B-spline (NURBS).

Card Summary:

Card 1. This card is required.

PATCHID	NR	PR					

Card 2. This card is required.

UNIR							

Card 3a. Include ceil[(NR + PR + 1)/4] of this card if UNIR = 0.

R1	R2	R3	R4

Card 3b. Include this card if UNIR ≠ 0.

RFIRST	RLAST		

Card 4. Include NR of this card.

X	Y	Z	WGT

Data Card Definitions:

Card 1	1	2	3	4	5	6	7	8
Variable	PATCHID	NR	PR					
Type	I	I	I					

VARIABLE	DESCRIPTION
PATCHID	Physical univariate NURBS patch ID. A unique number must be chosen.
NR	Number of control points in the local r-direction
PR	Polynomial degree of the basis in the local r-direction

Card 2	1	2	3	4	5	6	7	8
Variable	UNIR							
Type	I							
Default	0							

VARIABLE	DESCRIPTION
UNIR	Knot vector type in the local r-direction: EQ.0: Specify the entire knot vector in the local r-direction EQ.1: Uniform open knot vector in the local r-direction EQ.2: Uniform periodic knot vector in the local r-direction

Knot Vector Cards for the r-direction. Include ceil$[(\mathrm{NR} + \mathrm{PR} + 1)/4]$ cards if UNIR = 0.

Card 3a	1	2	3	4	5	6	7	8
Variable	R1		R2		R3		R4	
Type	F		F		F		F	

VARIABLE	DESCRIPTION
Ri	Knot values in the local r-direction with $i = 1, \ldots, \mathrm{NR} + \mathrm{PR} + 1$

Knot Vector Cards for the r-direction. Include this card if UNIR $\neq 0$, see Remark 1.

Card 3b	1	2	3	4	5	6	7	8
Variable	RFIRST		RLAST					
Type	F		F					

VARIABLE	DESCRIPTION
RFIRST	First knot value in the local r-direction

VARIABLE	DESCRIPTION
RLAST	Last knot value in the local *r*-direction

Control Point and Weight Cards. Include NR cards.

Card 4	1	2	3	4	5	6	7	8
Variable	X		Y		Z		WGT	
Type	F		F		F		F	
Default	none		none		none		1.0	

VARIABLE	DESCRIPTION
X*j*	Non-homogeneous control point coordinates in the global *x*-direction with $j = 1, \ldots,$ NR
Y*j*	Non-homogeneous control point coordinates in the global *y*-direction with $j = 1, \ldots,$ NR.
Z*j*	Non-homogeneous control point coordinates in the global *z*-direction with $j = 1, \ldots,$ NR.
WGT*j*	Control weights with $j = 1, \ldots,$ NR, see Remark 2.

Remarks:

1. **Uniform Knot Vectors.** RFIRST and RLAST define the interval for uniform knot spans. As an example suppose that NR = 4, PR = 3, RFIRST = 1, and RLAST = 8 which yields the following uniform open and uniform periodic knot vectors [1 1 1 1 8 8 8 8] and [1 2 3 4 5 6 7 8] for UNIR = 1 and UNIR = 2, respectively.

2. **Control Weights.** Control weights have to be positive and will otherwise be reset to the default unit value.

*IGA_2D_BASIS_TRANSFORM_XYZ

Purpose: Define a physical bivariate (rational) spline expressed as a basis transform.

Data Card. Include as many cards as desired. This input ends at the next keyword ("*") card.

Card 1	1	2	3	4	5	6	7	8
Variable	PATCHID	FILENAME						
Type	I	A70						

VARIABLE	DESCRIPTION
PATCHID	Physical bivariate (rational) spline patch ID
FILENAME	Name of file containing patch data; see Remark 1.

Remarks:

1. **Filename.** The current description of the input data is available as a separate document.

*IGA_2D_BEZIER_XYZ

Purpose: Define a physical bivariate (rational) spline using Bézier extraction.

NOTE: As of R15, this keyword is obsolete. Please use *IGA_-2D_BASIS_TRANSFORM_XYZ to define a bivariate (rational) spline expressed as a basis transform.

Data Card. Include as many cards as desired. This input ends at the next keyword ("*") card.

Card 1	1	2	3	4	5	6	7	8
Variable	PATCHID	FILENAME						
Type	I	A70						

VARIABLE	DESCRIPTION
PATCHID	Physical bivariate (rational) spline patch ID
FILENAME	Name of file containing patch data; see Remark 1.

Remarks:

1. **Filename.** The current description of the input data is available as a separate document.

*IGA_2D_BREP

Purpose: Define a two-dimensional boundary representation composed of parametric faces(s).

Card 1	1	2	3	4	5	6	7	8
Variable	BRID							
Type	I							
Default	none							

Parametric Face Cards. Include as many cards in the following format as desired. This input ends at the next keyword (“*”) card.

Card 2	1	2	3	4	5	6	7	8
Variable	FID1	FID2	FID3	FID4	FID5	FID6	FID7	FID8
Type	I	I	I	I	I	I	I	I
Default	none	none	none	none	none	none	none	none

VARIABLE	DESCRIPTION
BRID	Two-dimensional boundary representation ID. A unique number must be chosen.
FID*i*	Parametric face IDs, see *IGA_FACE_UVW.

*IGA_2D_NURBS_UVW

Purpose: Define a parametric bivariate non-uniform rational B-spline (NURBS).

Card Summary:

Card 1. This card is required.

PATCHID	NR	NS	PR	PS			

Card 2. This card is required.

UNIR	UNIS						

Card 3a. Include ceil$[(NR + PR + 1)/4]$ of this card if UNIR = 0.

R1	R2	R3	R4

Card 3b. Include this card if UNIR $\neq$ 0.

RFIRST	RLAST		

Card 4a. Include ceil$[(NS + PS + 1)/4]$ of this card if UNIS = 0.

S1	S2	S3	S4

Card 4b. Include this card if UNIS $\neq$ 0.

SFIRST	SLAST		

Card 5. Include NR $\times$ NS of this card.

U	V	W	WGT

Data Card Definitions:

Card 1	1	2	3	4	5	6	7	8
Variable	PATCHID	NR	NS	PR	PS			
Type	I	I	I	I	I			

VARIABLE	DESCRIPTION
PATCHID	Parametric bivariate NURBS patch ID. A unique number must be chosen.
NR	Number of control points in the local *r*-direction
NS	Number of control points in the local *s*-direction
PR	Polynomial degree of the basis in the local *r*-direction
PS	Polynomial degree of the basis in the local *s*-direction

Card 2	1	2	3	4	5	6	7	8
Variable	UNIR	UNIS						
Type	I	I						
Default	0	0						

VARIABLE	DESCRIPTION
UNIR	Knot vector type in the local *r*-direction: EQ.0: Specify the entire knot vector in the local *r*-direction. EQ.1: Uniform open knot vector in the local *r*-direction. EQ.2: Uniform periodic knot vector in the local *r*-direction.
UNIS	Knot vector type in the local *s*-direction: EQ.0: Specify the entire knot vector in the local *s*-direction. EQ.1: Uniform open knot vector in the local *s*-direction. EQ.2: Uniform periodic knot vector in the local *s*-direction.

Knot Vector Cards for the *r*-direction. If UNIR = 0, include ceil[(NR + PR + 1)/4] cards.

Card 3a	1	2	3	4	5	6	7	8
Variable	R1		R2		R3		R4	
Type	F		F		F		F	

VARIABLE	DESCRIPTION
R*i*	Knot values in the local *r*-direction with $i = 1, \ldots, \mathrm{NR} + \mathrm{PR} + 1$

Knot Vector Cards for the *r*-direction. Include this card if UNIR ≠ 0; see Remark 1.

Card 3b	1	2	3	4	5	6	7	8
Variable	RFIRST		RLAST					
Type	F		F					

VARIABLE	DESCRIPTION
RFIRST	First knot value in the local *r*-direction
RLAST	Last knot value in the local *r*-direction

Knot Vector Cards for the *s*-direction. Include ceil[(NS + PS + 1)/4] cards if UNIS = 0.

Card 4a	1	2	3	4	5	6	7	8
Variable	S1		S2		S3		S4	
Type	F		F		F		F	

VARIABLE	DESCRIPTION
S*j*	Knot values in the local *s*-direction with $j = 1, \ldots, \mathrm{NS} + \mathrm{PS} + 1$

Knot Vector Cards for the s-direction. Include this card if UNIS ≠ 0. See Remark 1.

Card 4b	1	2	3	4	5	6	7	8
Variable	SFIRST		SLAST					
Type	F		F					

VARIABLE	DESCRIPTION
SFIRST	First knot value in the local *s*-direction
SLAST	Last knot value in the local *s*-direction

Control Point and Weight Cards. Include NR × NS cards reflecting the connectivity. See Remark 2.

Card 5	1	2	3	4	5	6	7	8
Variable	U		V		W		WGT	
Type	F		F		F		F	
Default	none		none		none		1.0	

VARIABLE	DESCRIPTION
U*k*	Nonhomogeneous control point coordinates in the parametric *u*-direction with $k = 1, \ldots, \mathrm{NR} \times \mathrm{NS}$
V*k*	Nonhomogeneous control point coordinates in the parametric *v*-direction with $k = 1, \ldots, \mathrm{NR} \times \mathrm{NS}$
W*k*	Nonhomogeneous control point coordinates in the parametric *w*-direction with $k = 1, \ldots, \mathrm{NR} \times \mathrm{NS}$
WGT*k*	Control weights with $k = 1, \ldots, \mathrm{NR} \times \mathrm{NS}$; see Remark 3.

Remarks:

1. **Uniform Knot Vectors.** RFIRST and RLAST (SFIRST and SLAST) define the interval for uniform knot spans in the local *r*-direction (*s*-direction). As an

example suppose that NR = 4, PR = 3, RFIRST = 1, and RLAST = 8 which yields the following uniform open and uniform periodic knot vectors [1 1 1 1 8 8 8 8] and [1 2 3 4 5 6 7 8] for UNIR = 1 and UNIR = 2, respectively.

2. **Parametric Surface.** A parametric surface may be defined in the parametric space of a trivariate physical NURBS, meaning *IGA_3D_NURBS_XYZ, which requires the definition of (U, V, W) coordinates. Note that the parametric u-, v-, w-directions and (U, V, W) coordinates are equivalent to the local r-, s-, t-directions and (R,S,T) coordinates in the parametric space of the physical NURBS. The notation is adopted here only to distinguish between the parametric space of the parametric bivariate NURBS and the parametric space of the physical trivariate NURBS in which it is embedded in.

3. **Control Weights.** Control weights must be positive and will otherwise be reset to the default unit value.

*IGA_2D_NURBS_XYZ

Purpose: Define a physical bivariate non-uniform rational B-spline (NURBS).

Card Summary:

Card 1. This card is required.

PATCHID	NR	NS	PR	PS			

Card 2. This card is required.

UNIR	UNIS						

Card 3a. Include ceil$[(\mathrm{NR} + \mathrm{PR} + 1)/4]$ of this card if UNIR = 0.

R1	R2	R3	R4

Card 3b. Include this card if UNIR ≠ 0.

RFIRST	RLAST		

Card 4a. Include ceil$[(\mathrm{NS} + \mathrm{PS} + 1)/4]$ of this card if UNIS = 0.

S1	S2	S3	S4

Card 4b. Include this card if UNIS ≠ 0.

SFIRST	SLAST		

Card 5. Include NR × NS of this card.

X	Y	Z	WGT

Data Card Definitions:

Card 1	1	2	3	4	5	6	7	8
Variable	PATCHID	NR	NS	PR	PS			
Type	I	I	I	I	I			

VARIABLE	DESCRIPTION
PATCHID	Physical bivariate NURBS patch ID. A unique number must be chosen.
NR	Number of control points in the local r-direction
NS	Number of control points in the local s-direction
PR	Polynomial degree of the basis in the local r-direction
PS	Polynomial degree of the basis in the local s-direction

Card 2	1	2	3	4	5	6	7	8
Variable	UNIR	UNIS						
Type	I	I						
Default	0	0						

VARIABLE	DESCRIPTION
UNIR	Knot vector type in the local r-direction: EQ.0: Specify the entire knot vector in the local r-direction EQ.1: Uniform open knot vector in the local r-direction EQ.2: Uniform periodic knot vector in the local r-direction
UNIS	Knot vector type in the local s-direction: EQ.0: Specify the entire knot vector in the local s-direction EQ.1: Uniform open knot vector in the local s-direction EQ.2: Uniform periodic knot vector in the local s-direction

Knot Vector Cards for the *r*-direction. Include ceil[(NR + PR + 1)/4] cards if UNIR = 0.

Card 3a	1	2	3	4	5	6	7	8
Variable	R1		R2		R3		R4	
Type	F		F		F		F	

VARIABLE	DESCRIPTION
R*i*	Knot values in the local *r*-direction with $i = 1, \ldots, \mathrm{NR} + \mathrm{PR} + 1$

Knot Vector Cards for the *r*-direction. Include this card if UNIR ≠ 0. See Remark 1.

Card 3b	1	2	3	4	5	6	7	8
Variable	RFIRST		RLAST					
Type	F		F					

VARIABLE	DESCRIPTION
RFIRST	First knot value in the local *r*-direction
RLAST	Last knot value in the local *r*-direction

Knot Vector Cards for the *s*-direction. Include ceil[(NS + PS + 1)/4] cards if UNIS = 0.

Card 4a	1	2	3	4	5	6	7	8
Variable	S1		S2		S3		S4	
Type	F		F		F		F	

VARIABLE	DESCRIPTION
S*j*	Knot values in the local *s*-direction with $j = 1, \ldots, \mathrm{NS} + \mathrm{PS} + 1$

Knot Vector Cards for the *s*-direction. Include this card if UNIS ≠ 0. See Remark 1.

Card 4b	1	2	3	4	5	6	7	8
Variable	SFIRST		SLAST					
Type	F		F					

VARIABLE	DESCRIPTION
SFIRST	First knot value in the local *s*-direction
SLAST	Last knot value in the local *s*-direction

Control Point and Weight Cards. Include NR × NS cards reflecting the connectivity.

Card 5	1	2	3	4	5	6	7	8
Variable	X		Y		Z		WGT	
Type	F		F		F		F	
Default	none		none		none		1.0	

VARIABLE	DESCRIPTION
X*k*	Nonhomogeneous control point coordinates in the global *x*-direction with $k = 1, \ldots, \mathrm{NR} \times \mathrm{NS}$.
Y*k*	Nonhomogeneous control point coordinates in the global *y*-direction with $k = 1, \ldots, \mathrm{NR} \times \mathrm{NS}$.
Z*k*	Nonhomogeneous control point coordinates in the global *z*-direction with $k = 1, \ldots, \mathrm{NR} \times \mathrm{NS}$.
WGT*k*	Control weights with $k = 1, \ldots, \mathrm{NR} \times \mathrm{NS}$. See Remark 2.

Remarks:

1. **Uniform Knot Vectors.** RFIRST and RLAST (SFIRST and SLAST) define the interval for uniform knot spans in the local *r*-direction (*s*-direction). As an example suppose that NR = 4, PR = 3, RFIRST = 1, and RLAST = 8 which yields the

following uniform open and uniform periodic knot vectors [1 1 1 1 8 8 8 8] and [1 2 3 4 5 6 7 8] for UNIR = 1 and UNIR = 2, respectively.

2. **Control Weights.** Control weights must be positive and will otherwise be reset to the default unit value.

*IGA_3D_BASIS_TRANSFORM_XYZ

Purpose: Define a physical trivariate (rational) spline expressed as a basis transform.

Data Card. Include as many cards as desired. This input ends at the next keyword ("*") card.

Card 1	1	2	3	4	5	6	7	8
Variable	PATCHID	FILENAME						
Type	I	A70						

VARIABLE	DESCRIPTION
PATCHID	Physical trivariate (rational) spline patch ID
FILENAME	Name of file containing patch data; see Remark 1.

Remarks:

1. **Filename.** The current description of the input data is available as a separate document.

*IGA_3D_BEZIER_XYZ

Purpose: Define a physical trivariate (rational) spline using Bézier extraction.

NOTE: As of R15, this keyword is obsolete. Please use *IGA_3D_BASIS_TRANSFORM_XYZ to define a trivariate (rational) spline expressed as a basis transform.

Data Card. Include as many cards as desired. This input ends at the next keyword ("*") card.

Card 1	1	2	3	4	5	6	7	8
Variable	PATCHID	FILENAME						
Type	I	A70						

VARIABLE	DESCRIPTION
PATCHID	Physical trivariate (rational) spline patch ID
FILENAME	Name of file containing patch data; see Remark 1.

Remarks:

1. **Filename.** The current description of the input data is available as a separate document.

*IGA_3D_NURBS_XYZ

Purpose: Define a physical trivariate non-uniform rational B-spline (NURBS).

Card Summary:

Card 1. This card is required.

PATCHID	NR	NS	NT	PR	PS	PT	

Card 2. This card is required.

UNIR	UNIS	UNIT					

Card 3a. Include ceil$[(\mathrm{NR} + \mathrm{PR} + 1)/4]$ of this card if UNIR = 0.

R1	R2	R3	R4

Card 3b. Include this card if UNIR ≠ 0.

RFIRST	RLAST		

Card 4a. Include ceil$[(\mathrm{NS} + \mathrm{PS} + 1)/4]$ of this card if UNIS = 0.

S1	S2	S3	S4

Card 4b. Include this card if UNIS ≠ 0.

SFIRST	SLAST		

Card 5a. Include ceil$[(\mathrm{NT} + \mathrm{PT} + 1)/4]$ of this card if UNIT = 0.

T1	T2	T3	T4

Card 5b. Include this card if UNIT ≠ 0.

TFIRST	TLAST		

Card 6. Include NR × NS × NT of this card.

X	Y	Z	WGT

Data Card Definitions:

Card 1	1	2	3	4	5	6	7	8
Variable	PATCHID	NR	NS	NT	PR	PS	PT	
Type	I	I	I	I	I	I	I	

VARIABLE	DESCRIPTION
PATCHID	Physical trivariate NURBS patch ID. A unique number must be chosen.
NR	Number of control points in the local *r*-direction
NS	Number of control points in the local *s*-direction
NT	Number of control points in the local *t*-direction
PR	Polynomial degree of the basis in the local *r*-direction
PS	Polynomial degree of the basis in the local *s*-direction
PT	Polynomial degree of the basis in the local *t*-direction

Card 2	1	2	3	4	5	6	7	8
Variable	UNIR	UNIS	UNIT					
Type	I	I	I					
Default	0	0	0					

VARIABLE	DESCRIPTION
UNIR	Knot vector type in the local *r*-direction: EQ.0: Specify the entire knot vector in the local *r*-direction EQ.1: Uniform open knot vector in the local *r*-direction EQ.2: Uniform periodic knot vector in the local *r*-direction

VARIABLE	DESCRIPTION
UNIS	Knot vector type in the local s-direction: EQ.0: Specify the entire knot vector in the local s-direction EQ.1: Uniform open knot vector in the local s-direction EQ.2: Uniform periodic knot vector in the local s-direction
UNIT	Knot vector type in the local t-direction: EQ.0: Specify the entire knot vector in the local t-direction EQ.1: Uniform open knot vector in the local t-direction EQ.2: Uniform periodic knot vector in the local t-direction

Knot Vector Cards for the r-direction. Include ceil[(NR + PR + 1)/4] cards if UNIR = 0.

Card 3a	1	2	3	4	5	6	7	8
Variable	R1		R2		R3		R4	
Type	F		F		F		F	

VARIABLE	DESCRIPTION
Ri	Knot values in the local r-direction with $i = 1, \ldots, \mathrm{NR} + \mathrm{PR} + 1$

Knot Vector Cards for the r-direction. Include this card if UNIR ≠ 0. See Remark 1.

Card 3b	1	2	3	4	5	6	7	8
Variable	RFIRST		RLAST					
Type	F		F					

VARIABLE	DESCRIPTION
RFIRST	First knot value in the local r-direction
RLAST	Last knot value in the local r-direction

Knot Vector Cards for the *s*-direction. Include ceil[(NS + PS + 1)/4] cards if UNIS = 0.

Card 4a	1	2	3	4	5	6	7	8
Variable	S1		S2		S3		S4	
Type	F		F		F		F	

VARIABLE	DESCRIPTION
S*j*	Knot values in the local *s*-direction with $j = 1, \ldots, \mathrm{NS} + \mathrm{PS} + 1$

Knot Vector Cards for the *s*-direction. Include this card if UNIS ≠ 0. See Remark 1.

Card 4b	1	2	3	4	5	6	7	8
Variable	SFIRST		SLAST					
Type	F		F					

VARIABLE	DESCRIPTION
SFIRST	First knot value in the local *s*-direction
SLAST	Last knot value in the local *s*-direction

Knot Vector Cards for the *t*-direction. Include ceil[(NT + PT + 1)/4] cards if UNIT = 0.

Card 5a	1	2	3	4	5	6	7	8
Variable	T1		T2		T3		T4	
Type	F		F		F		F	

VARIABLE	DESCRIPTION
T*k*	Knot values in the local *t*-direction with $k = 1, \ldots, \mathrm{NT} + \mathrm{PT} + 1$

Knot Vector Cards for the t-direction. Include this card if UNIT ≠ 0. See Remark 1.

Card 5b	1	2	3	4	5	6	7	8
Variable	TFIRST		TLAST					
Type	F		F					

VARIABLE	DESCRIPTION
TFIRST	First knot value in the local t-direction
TLAST	Last knot value in the local t-direction

Control Point and Weight Cards. Include NR × NS × NT cards reflecting the connectivity.

Card 6	1	2	3	4	5	6	7	8
Variable	X		Y		Z		WGT	
Type	F		F		F		F	
Default	none		none		none		1.0	

VARIABLE	DESCRIPTION
Xl	Nonhomogeneous control point coordinates in the global x-direction with l = 1, …, NR × NS × NT
Yl	Nonhomogeneous control point coordinates in the global y-direction with l = 1, …, NR × NS × NT
Zl	Non-homogeneous control point coordinates in the global z-direction with l = 1, …, NR × NS × NT
WGTl	Control weights with l = 1, …, NR × NS × NT. See Remark 2.

Remarks:

1. **Uniform Knot Vectors.** RFIRST and RLAST (SFIRST and SLAST or TFIRST and TLAST) define the interval for uniform knot spans in the local r-direction (s-

direction or *t*-direction). As an example suppose that NR = 4, PR = 3, RFIRST = 1, and RLAST = 8 which yields the following uniform open and uniform periodic knot vectors [1 1 1 1 8 8 8 8] and [1 2 3 4 5 6 7 8] for UNIR = 1 and UNIR = 2, respectively.

2. **Control Weights.** Control weights must be positive and will otherwise be reset to the default unit value.

*IGA_EDGE_UVW_{OPTION}

Purpose: Define a parametric edge, meaning a trimmed and oriented parametric univariate non-uniform rational B-spline (NURBS). Parametric edges are used to compose one-dimensional boundary representations (see *IGA_1D_BREP) and trim parametric as well as physical faces (see *IGA_FACE_UVW and *IGA_FACE_XYZ). In addition, a parametric edge may play a role in defining (1) topological relations among physical faces and (2) boundary conditions and/or constraints. See Remarks 1 and 2, respectively.

Available options include:

<BLANK>

BASIS_TRANSFORM

Card Summary:

Card 1. This card is required.

EID	EXYZID	PATCHID	SENSE	RSTART	REND

Card 2. Included this card if the BASIS_TRANSFORM keyword option is used.

ELID	EDGEID						

Data Card Definitions:

Card 1	1	2	3	4	5	6	7	8
Variable	EID	EXYZID	PATCHID	SENSE	RSTART		REND	
Type	I	I	I	I	F		F	
Default	none	none	none	0	RFIRST		RLAST	

VARIABLE	DESCRIPTION
EID	Parametric edge ID. A unique number must be chosen.
EXYZID	Physical edge ID. See *IGA_EDGE_XYZ and Remarks 1 and 3.

VARIABLE	DESCRIPTION
PATCHID	Parametric univariate NURBS patch ID. See *IGA_1D_NURBS_-UVW and Remarks 2, 3, and 5. PATCHID is ignored for the BASIS_TRANSFORM keyword option.
SENSE	Sense of orientation with respect to the physical edge (ignored for the BASIS_TRANSFORM keyword option). See Remarks 3 and 5. EQ.0: Same (default) EQ.1: Reversed
RSTART	Parametric coordinate defining the start of the trimmed parametric NURBS. See Remarks 4 and 5. RSTART is ignored for the BASIS_-TRANSFORM keyword option.
REND	Parametric coordinate defining the end of the trimmed parametric NURBS. See Remarks 4 and 5. REND is ignored for the BASIS_-TRANSFORM keyword option

Element Card. Include this card if using the BASIS_TRANSFORM keyword option.

Card 2	1	2	3	4	5	6	7	8
Variable	ELID	EDGEID						
Type	I	I						
Default	none	none						

VARIABLE	DESCRIPTION
ELID	Element ID local to a basis transform. See *IGA_2D_BASIS_-TRANSFORM_XYZ and Remark 6. A unique number must be chosen.
EDGEID	Edge ID. See Remark 7. The following convention is used to identify parametric edges on a parent element $[-1, +1]^2$: EQ.1: $u = -1, v \in [-1, +1]$ EQ.2: $u = +1, v \in [-1, +1]$ EQ.3: $v = -1, u \in [-1, +1]$ EQ.4: $v = +1, u \in [-1, +1]$

Remarks:

1. **Topology.** Parametric edges are the constituents of one-dimensional boundary representations (see *IGA_1D_BREP) which specify the exterior of a physical face (see *IGA_FACE_XYZ). Parametric edges referencing the same physical edge, meaning EXYZID, identify the topological relation between their parent physical faces.

2. **Boundary conditions and constraints.** A parametric edge may be invoked to define a curve segment in/on an isogeometric shell or solid; see *IGA_SHELL and *IGA_SOLID. In this case, the control points of a parametric univariate NURBS referenced by PATCHID are defined in the parametric space of its parent physical object. Consequently, a parametric edge may be defined in the parametric space of an n-variate physical NURBS, such as *IGA_nD_NURBS_XYZ with $n = 2$ or 3, which requires the definition of (U, V) or (U, V, W) control point coordinates, respectively. Alternatively, a parametric edge may be defined in the parametric space of an element in a basis transform (see *IGA_2D_BASIS_-TRANSFORM_XYZ). In this case, the selection of a parametric edge is restricted to the edges of the parent element. See Remarks 6 and 7.

3. **Sense of orientation.** The orientation of the parametric edge and the parametric univariate NURBS always agree. The SENSE flag indicates if the orientation of the parametric and physical edges agrees. Consider, for instance, two patches connected along an edge as schematically shown in the figure below. The parametric edges f_2 and f_8 share the same physical edge e_2. The direction of f_2 and e_2 is the same, consequently SENSE = 0. In contrast, f_8 and e_2 point in opposite directions, hence SENSE = 1.

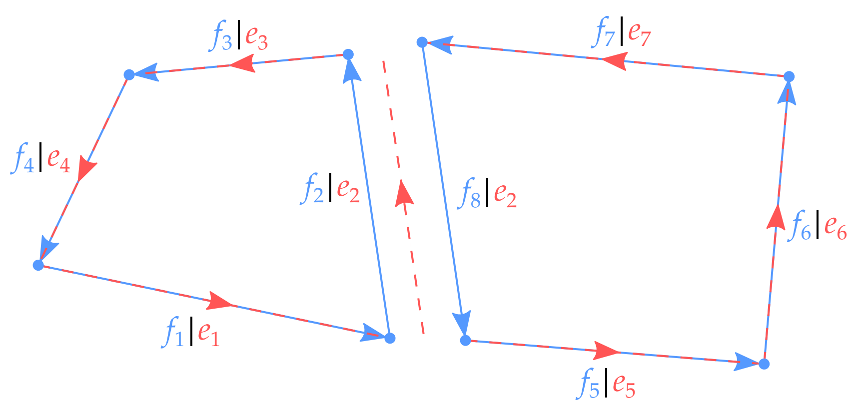

Figure 26-1. Schematic of two patches connected along an edge. Parametric edges are blue while physical edges are red.

4. **Trimming.** Parametric coordinates are used to trim the underlying parametric univariate NURBS. The parametric coordinates should have distinct values such that RSTART < REND. Out of bound parametric coordinates are disregarded and no trimming is performed at the respective ends.

5. **Fields ignored with BASIS_TRANSFORM.** The PATCHID, SENSE, RSTART, and REND fields on Card 1 are not used, and consequently do not need to be defined, if the BASIS_TRANSFORM keyword option is used.

6. **Local element ID.** Basis transforms (see *IGA_2D_BASIS_TRANSFORM_XYZ) by construction rely on elementwise local parameterizations. Consequently, unique definition of a parametric edge requires the local element ID in the patch containing the edge.

7. **Parametric feature edges/lines.** Relevant parametric feature edges/lines are captured by the underlying parameterization of a basis transform (see *IGA_-2D_BASIS_TRANSFORM_XYZ) which thereby facilitates simplified selection of a parametric edge in Card 2.

*IGA_EDGE_XYZ

Purpose: Define a physical edge, meaning a trimmed and oriented physical univariate non-uniform rational B-spline (NURBS). A physical edge is currently only used to define topological relations among different physical faces; see *IGA_EDGE_UVW and *IGA_-FACE_XYZ for more details.

Edge Cards. Include as many cards in the following format as desired. This input ends at the next keyword ("*") card.

Card 1	1	2	3	4	5	6	7	8
Variable	EID	PATCHID	ORI	PIDSTART	PIDEND	PSID		
Type	I	I	I	I	I	I		
Default	none	none	0	0	0	none		

VARIABLE	DESCRIPTION
EID	Physical edge ID. A unique number must be chosen.
PATCHID	Physical univariate NURBS patch ID; see *IGA_1D_NURBS_XYZ.
ORI	Orientation with respect to the physical univariate NURBS. See Remark 1. EQ.0: Same (default) EQ.1: Reversed
PIDSTART	Parametric point ID defining the start of the trimmed physical NURBS. If PIDSTART = 0, the physical univariate NURBS is not trimmed at its start; see Remarks 1, 2, and 3.
PIDEND	Parametric point ID defining the end of the trimmed physical NURBS. If PIDEND = 0, the physical univariate NURBS is not trimmed at its end; see Remarks 1, 2, and 3.
PSID	Parametric point set ID. See *IGA_POINT_UVW and *SET_-IGA_-POINT_UVW. See Remark 4.

Remarks:

1. **Orientation.** The orientation of a physical edge is defined by the parametric points referenced by PIDSTART and PIDEND or, if none of the parametric points are defined, by the orientation flag ORI. Simultaneous use of the parametric points and the orientation flag is only required if the underlying physical NURBS curve is closed. The orientation convention is illustrated in the figure below where the blue solid line is the physical univariate NURBS curve, the red dashed line is the physical edge, and the black circle and dot denote the parametric points specifying the start and end of the edge, respectively.

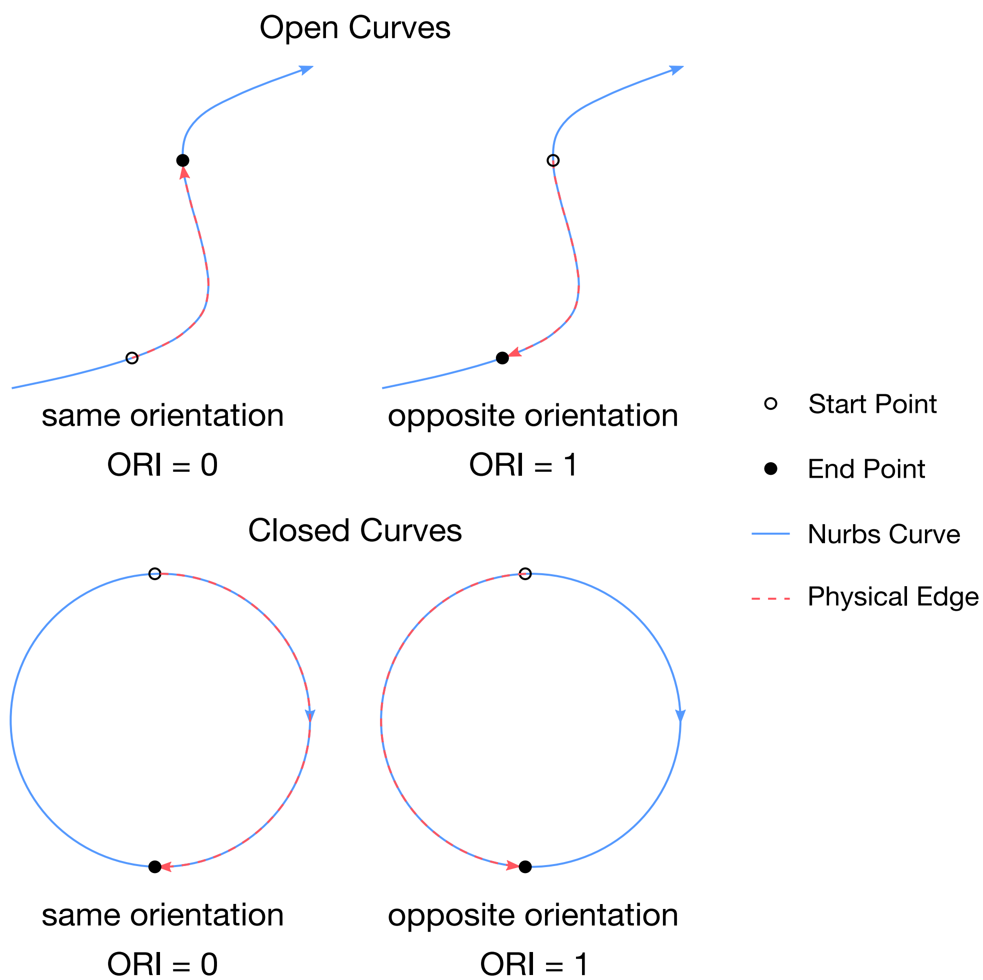

Figure 26-2. Orientation for different physical edges compared to the physical NURBS curve

2. **Trimming.** Parametric points determine where to trim the underlying physical univariate NURBS. Thus, the parametric points should be within the knot vector. An out of bound parametric point is disregarded with no trimming performed at that end.

3. **Topology.** Parametric points are also help establish topological relations among different physical edges.

4. **Dependent Parametric Point Set.** The collection of parametric points is defined within the parametric space of the underlying univariate NURBS and used in boundary condition and/or constraint definition(s).

*IGA_FACE_UVW_{OPTION}

Purpose: Define a parametric face, meaning a trimmed and oriented parametric bivariate non-uniform rational B-spline (NURBS). Parametric faces are used to compose two-dimensional boundary representations (see *IGA_2D_BREP) and trim physical volumes (see *IGA_VOLUME_XYZ). In addition, a parametric face may play a role in defining (1) topological relations among physical volumes and (2) boundary conditions and/or constraints; see Remarks 1 and 2, respectively.

Available options include:

<BLANK>

BASIS_TRANSFORM

Card Summary:

Card 1. This card is required.

FID	FXYZID	PATCHID	SENSE				

Card 2a. Include this card if no keyword option is used. Include as many cards in the following format as desired. This input ends at the next keyword ("*") card.

BRID1	BRID2	BRID3	BRID4	BRID5	BRID6	BRID7	BRID8

Card 2b. Include this card if using the BASIS_TRANSFORM keyword option.

ELID	FACEID						

Data Card Definitions:

Card 1	1	2	3	4	5	6	7	8
Variable	FID	FXYZID	PATCHID	SENSE				
Type	I	I	I	I				
Default	none	none	none	0				

VARIABLE	DESCRIPTION
FID	Parametric face ID. A unique number must be chosen.

VARIABLE	DESCRIPTION
FXYZID	Physical face ID. See *IGA_FACE_XYZ and Remarks 1 and 3.
PATCHID	Parametric bivariate NURBS patch ID. See *IGA_2D_NURBS_UVW and Remarks 2 and 3. Ignored for the BASIS_TRANSFORM keyword option (see Remark 4).
SENSE	Sense of orientation with respect to the physical face. Ignored for the BASIS_TRANSFORM keyword option. See Remarks 3 and 4. EQ.0: Same (default) EQ.1: Reversed

Boundary Representation Cards. Include boundary representations defining the parametric face if no keyword option (<BLANK>) is used, see Remark 1. Include as many cards in the following format as desired. This input ends at the next keyword ("*") card.

Card 2a	1	2	3	4	5	6	7	8
Variable	BRID1	BRID2	BRID3	BRID4	BRID5	BRID6	BRID7	BRID8
Type	I	I	I	I	I	I	I	I
Default	none	none	none	none	none	none	none	none

VARIABLE	DESCRIPTION
BRIDi	One-dimensional boundary representation IDs (see *IGA_1D_BREP) with $i = 1, \ldots, n$ and $n > 0$

Element Card. Include this card if the BASIS_TRANSFORM keyword option is used.

Card 2b	1	2	3	4	5	6	7	8
Variable	ELID	FACEID						
Type	I	I						
Default	none	none						

VARIABLE	DESCRIPTION
ELID	Element ID local to a trivariate basis transform. See *IGA_3D_BASIS_TRANSFORM_XYZ and Remark 6. A unique number must be chosen.
FACEID	Face ID (see Remark 6). The following convention is used to identify parametric faces on a parent element $[-1,+1]^3$: EQ.1: $u = -1, \mathrm{v}, \mathrm{w} \in [-1,+1]$ EQ.2: $u = +1, \mathrm{v}, \mathrm{w} \in [-1,+1]$ EQ.3: $v = -1, \mathrm{u}, \mathrm{w} \in [-1,+1]$ EQ.4: $v = +1, \mathrm{u}, \mathrm{w} \in [-1,+1]$ EQ.5: $w = -1, \mathrm{u}, \mathrm{v} \in [-1,+1]$ EQ.6: $w = +1, \mathrm{u}, \mathrm{v} \in [-1,+1]$

Remarks:

1. **Topology.** Parametric faces are the constituents of two-dimensional boundary representations (see *IGA_2D_BREP) which specify the exterior of a physical volume (see *IGA_VOLUME_XYZ). Parametric faces referencing the same physical face, meaning FXYZID, identify the topological relation between their parent physical volumes.

2. **Boundary conditions and constraints.** A parametric face may be invoked to define a surface segment in/on an isogeometric solid; see *IGA_SOLID. In this case, the control points of a parametric bivariate NURBS referenced by PATCHID are defined in the parametric space of its parent physical object. Consequently, a parametric face may be defined in the parametric space of a trivariate physical NURBS (see *IGA_3D_NURBS_XYZ) which requires the definition of (U, V, W) control point coordinates. Alternatively, a parametric face may be defined in the parametric space of an element within a trivariate basis transform (see *IGA_3D_BASIS_TRANSFORM_XYZ). In the latter case, the selection of a parametric face is restricted to the faces of the parent element, see Remarks 5 and 6.

3. **Sense of orientation.** The orientation of the parametric face and the parametric bivariate NURBS always agree. The SENSE flag indicates if the orientation of the parametric and physical faces agrees.

4. **Fields ignored for BASIS_TRANSFORM keyword option.** The PATCHID and SENSE fields on Card 1 are not used, and consequently do not need to be defined, if the BASIS_TRANSFORM keyword option is used.

5. **Local element ID.** Trivariate basis transforms (see *IGA_3D_BASIS_TRANSFORM_XYZ) by construction rely on elementwise local parameterizations. Consequently, the unique definition of a parametric face requires the local element ID in the patch containing the face.

6. **Parametric feature surfaces.** Relevant parametric feature surfaces are captured by the underlying parameterization of a trivariate basis transform (see *IGA_3D_BASIS_TRANSFORM_XYZ) which thereby facilitates simplified selection of a parametric face in Card 2b.

*IGA_FACE_XYZ_{OPTION}

Purpose: Define a physical face, meaning a trimmed and oriented physical bivariate non-uniform rational B-spline (NURBS) or a physical bivariate basis transform. A physical face is used to define isogeometric shells (see *IGA_SHELL) as well as boundary conditions and/or constraints on its (sub)surface.

Available options include:

<BLANK>

BASIS_TRANSFORM

Card Summary:

Card 1. This card is required.

FID	PATCHID	ORI	PSID	ESID			

Card 2a. Include this card if no keyword option is used. Include as many cards in the following format as desired. This input ends at the next keyword ("*") card.

BRID1	BRID2	BRID3	BRID4	BRID5	BRID6	BRID7	BRID8

Card 2b. Include this card if using the BASIS_TRANSFORM keyword option.

ELID1	ELID2	ELID3	ELID4	ELID5	ELID6	ELID7	ELID8

Data Card Definitions:

Card 1	1	2	3	4	5	6	7	8
Variable	FID	PATCHID	ORI	PSID	ESID			
Type	I	I	I	I	I			
Default	none	none	0	none	none			

VARIABLE	DESCRIPTION
FID	Physical face ID. A unique number must be chosen.
PATCHID	Depending on the keyword option either a physical bivariate NURBS patch ID for no keyword option (see *IGA_2D_NURBS_-

VARIABLE	DESCRIPTION
	XYZ) or a bivariate basis transform patch ID for BASIS_TRANSFORM keyword option (see *IGA_2D_BASIS_TRANSFORM_XYZ).
ORI	Orientation with respect to the physical bivariate NURBS. EQ.0: Same (default) EQ.1: Reversed
PSID	Parametric point set ID; see *IGA_POINT_UVW, *SET_IGA_POINT_UVW, and Remark 3.
ESID	Parametric edge set ID; see *IGA_EDGE_UVW, *SET_IGA_EDGE_UVW, and Remark 3.

Boundary Representation Cards. Include boundary representations defining the physical face if no keyword option (<BLANK>) is used, see Remarks 1, 2, and 4. Include as many cards in the following format as desired. This input ends at the next keyword ("*") card.

Card 2a	1	2	3	4	5	6	7	8
Variable	BRID1	BRID2	BRID3	BRID4	BRID5	BRID6	BRID7	BRID8
Type	I	I	I	I	I	I	I	I
Default	none	none	none	none	none	none	none	none

VARIABLE	DESCRIPTION
BRID*i*	One-dimensional boundary representation IDs, with $i = 1, \ldots, n$ and $n > 0$. See *IGA_1D_BREP and Remarks 1, 2, and 4.

Element Cards. Include element cards if the BASIS_TRANSFORM keyword option is used, see Remark 4. Include as many cards in the following format as desired. This input ends at the next keyword (“*”) card.

Card 2b	1	2	3	4	5	6	7	8
Variable	ELID1	ELID2	ELID3	ELID4	ELID5	ELID6	ELID7	ELID8
Type	I	I	I	I	I	I	I	I
Default	none	none	none	none	none	none	none	none

VARIABLE	DESCRIPTION
ELID*i*	Element IDs, with $i = 1, \ldots, n$ and $n > 0$, local to a bivariate basis transform. See *IGA_2D_BASIS_TRANSFORM_XYZ and Remark 4.

Remarks:

1. **Trimming.** One-dimensional boundary representations, also called trimming loops, are used to trim the underlying bivariate NURBS. The orientation of the trimming loops uniquely define trimming, meaning travelling along the loop. The domain on the right-hand side of the loop is removed.

2. **Topology.** To establish topological relations among physical faces, at least a single boundary representation must be included.

3. **Dependent Parametric Object Sets.** The collection of parametric points and edges are defined within the parametric space of the underlying bivariate NURBS and used in boundary condition and/or constraint definition(s).

4. **Partitioning.** Multiple isogeometric shells may be defined using the same underlying geometry. This may be done to assign different materials and/or sections and consequently subdivide the geometry into separate parts. To this end, the definition of multiple physical faces is required. Based on the keyword option, two cases can be distinguished:

    a) Without the keyword option (<BLANK>), the geometry is defined using a bivariate physical NURBS (see *IGA_2D_NURBS_XYZ). Multiple physical faces may be defined using different one-dimensional boundary representations (see *IGA_1D_BREP) on Card 2a.

b) With the BASIS_TRANSFORM keyword option, the geometry is defined using a bivariate basis transform (see *IGA_2D_BASIS_TRANSFORM_-XYZ). Multiple physical faces may be defined by including a different set of elements on Card 2b.

*IGA_INCLUDE_BEZIER

Purpose: Include novel computer-aided geometric definitions by virtue of Bézier extraction to perform isogeometric analysis. For more information on the include file format, please contact LS-DYNA support.

> **NOTE:** As of R14, this keyword is obsolete. Please use *IGA_2D_BEZIER_XYZ and *IGA_3D_BEZIER_XYZ to define bi- and trivariate (rational) splines using Bézier extraction, respectively.

Card 1	1	2	3	4	5	6	7	8
Variable	FILENAME							
Type	C							
Default	none							

Card 2	1	2	3	4	5	6	7	8
Variable	FILETYPE	PID	DIM					
Type	I	I	I					
Default	none	none	none					

VARIABLE	DESCRIPTION
FILENAME	Name of the file to be included; see Remark 1.
FILETYPE	Type of the file to be included: EQ.1: ASCII
PID	Part ID
DIM	Parametric dimension: EQ.2: Surface EQ.3: Volume

Remarks:

1. **Multiple Patches.** The include file may contain multiple patches of the same parametric dimension which will also share the same part, and consequently, material and section IDs. Some properties may be set on a patch by patch basis (see *IGA_SHELL and *IGA_SOLID for DIM = 2 and DIM = 3, respectively)

*IGA_INTEGRATION_SHELL_REDUCE

Purpose: Apply a reduced Generalized Gaussian Quadrature rule to IGA shells. To activate this integration rule, set IRL = 3 in *SECTION_IGA_SHELL.

Card 1	1	2	3	4	5	6	7	8
Variable	PATCHID	NRDR	NRDS					
Type	I	I	I					
Default	0	0	0					

VARIABLE	DESCRIPTION
PATCHID	Patch ID defined in *IGA_SHELL: EQ.0: Apply to all IGA shell patches
NRDR	Reduced degree in the *r*-direction: EQ.0: Full integration EQ.1: Reduced by 1 EQ.2: Reduced by 2
NRDS	Reduced degree in the *s*-direction: EQ.0: Full integration EQ.1: Reduced by 1 EQ.2: Reduced by 2

*IGA_INTEGRATION_SOLID_REDUCE

Purpose: Apply a reduced Generalized Gaussian Quadrature rule to IGA solids. Activating this integration rule requires setting IR = 3 in *SECTION_IGA_SOLID.

Card 1	1	2	3	4	5	6	7	8
Variable	PATCHID	NRDR	NRDS	NRDT				
Type	I	I	I	I				
Default	0	0	0	0				

VARIABLE	DESCRIPTION
PATCHID	PATCH ID defined in *IGA_SOLID: EQ.0: Apply to all IGA solid patches.
NRDR	Reduced degree in the *r*-direction: EQ.0: Full integration EQ.1: Reduced by 1 EQ.2: Reduced by 2
NRDS	Reduced degree in the *s*-direction: EQ.0: Full integration EQ.1: Reduced by 1 EQ.2: Reduced by 2
NRDT	Reduced degree in the *t*-direction: EQ.0: Full integration EQ.1: Reduced by 1 EQ.2: Reduced by 2

IGA_MASS_*OPTION

Available options include:

POINT_UVW

EDGE_UVW

FACE_XYZ

SET_POINT_UVW

SET_EDGE_UVW

SET_FACE_XYZ

Purpose: Define a uniformly distributed mass on IGA entities.

Input Cards. Include as many cards as necessary. This input ends at the next keyword ("*") card.

Card 1	1	2	3	4	5	6	7	8
Variable	ID	TMASS	DMASS					
Type	I	F	F					
Default	none	0.0	0.0					

VARIABLE	DESCRIPTION
ID	Parametric point, parametric point set, parametric edge, parametric edge set, physical face, or physical face set ID, depending on the choice of keyword option.
TMASS	Mass added to IGA entity. See Remark 1.
DMASS	Uniformly distributed mass added to IGA entity. See Remark 1.

Remarks:

1. **Added mass.** The final added mass is computed as the sum of TMASS divided by length (for parametric edges) or area (for physical faces) of the IGA entity and DMASS. LS-DYNA computes the length or area of the IGA entity. The unit of

TMASS is [MASS] while DMASS is [MASS]/[LENGTH or AREA]. Numerical integration determines the corresponding added mass at control points.

IGA_POINT_UVW_*{OPTION}

Purpose: Define a parametric point. A parametric point may play a role in defining (1) topological relations among physical edges and (2) boundary conditions and/or constraints; see Remarks 1 and 2, respectively.

Available options include:

<BLANK>

BASIS_TRANSFORM

Card Summary:

Card 1. This card is required.

PID	NID	U	V	W

Card 2. Include this card if using the BASIS_TRANSFORM keyword option.

ELID							

Data Card Definitions:

Card 1	1	2	3	4	5	6	7	8
Variable	PID	NID	U		V		W	
Type	I	I	F		F		F	
Default	none	none	none		none		none	

VARIABLE	DESCRIPTION
PID	Parametric point ID. A unique number must be chosen.
NID	Node IDs; see *NODE and Remark 3.
U	Coordinates in the parametric u-direction
V	Coordinates in the parametric v-direction
W	Coordinates in the parametric w-direction

Element Card. Include this card if using the BASIS_TRANSFORM keyword option.

Card 2	1	2	3	4	5	6	7	8
Variable	ELID							
Type	I							
Default	none							

VARIABLE	DESCRIPTION
ELID	Element ID local to a basis transform. See *IGA_nD_BASIS_TRANSFORM_XYZ with n = 2 or 3 and Remark 4. A unique number must be chosen.

Remarks:

1. **Topology.** Parametric points may specify the starting and ending point of a physical edge; see *IGA_EDGE_XYZ. Parametric points referencing the same node (also interpreted as a physical point), meaning NID, identify the topological relation between their parent physical edges.

2. **Boundary conditions and constraints.** A parametric point may be invoked to define a discrete location in/on an isogeometric shell or solid; see *IGA_SHELL and *IGA_SOLID. In this case, the coordinates of the parametric point are defined in the parametric space of its parent physical object. Consequently, a parametric point may be defined in the parametric space of an n-variate physical NURBS, that is, *IGA_nD_NURBS_XYZ with n = 1, 2, or 3, which requires the definition of (U), (U, V), and (U, V, W) coordinates, respectively. Alternatively, a parametric point may be defined in the parametric space of an element within an n-variate basis transform, that is, *IGA_nD_BASIS_TRANSFORM_XYZ with n = 2, or 3, which requires the definition of (U, V), and (U, V, W) coordinates, respectively.

3. **The role of nodes.** Nodes can be interpreted as physical points.

4. **Local element ID.** Basis transforms (see *IGA_2D/3D_BASIS_TRANSFORM_XYZ) by construction rely on elementwise local parameterizations. Consequently, a unique definition of a parametric point requires the local element ID in the patch containing the point.

*IGA_REFINE_SHELL

Purpose: Define refinement for isogeometric shells (see *IGA_SHELL). This capability is limited to shells parameterized by bivariate structured splines (see *IGA_FACE_XYZ and *IGA_2D_NURBS_XYZ).

Card Summary:

Card 1. This card is required.

RID	RTYP						

Card 2. Include this card if RTYP = 1 or 2.

HRTYP	RR	RS					

Card 3. Include this card if RTYP = 2 or 3.

TR	TS						

Data Card Definitions:

Card 1	1	2	3	4	5	6	7	8
Variable	RID	RTYP						
Type	I	I						
Default	none	none						

VARIABLE	DESCRIPTION
RID	Isogeometric shell refinement ID. A unique number must be chosen.
RTYP	Refinement type: EQ.1: *h*-refinement (knot insertion) EQ.2: *k*-refinement, meaning *p*-refinement followed by *h*-refinement EQ.3: *p*-refinement (degree elevation)

Knot Insertion Card. Include this card if RTYP = 1 or 2.

Card 2	1	2	3	4	5	6	7	8
Variable	HRTYP	RR	RS					
Type	I	F	F					
Default	none	none	none					

VARIABLE	DESCRIPTION
HRTYP	h-refinement type: EQ.1: Number of subdivisions-based. Each nonzero knot span is subdivided to $\mathrm{NINT(RR)} \times \mathrm{NINT(RS)}$ equal knot spans. Here, $\mathrm{NINT}(x)$ rounds x to the nearest integer.
RR	NINT(RR) is the number of equal parametric segments in the local r-direction. NINT(RR) means the input RR is rounded to the nearest integer.
RS	NINT(RS) is the number of equal parametric segments in the local s-direction. NINT(RS) means the input RS is rounded to the nearest integer.

Polynomial Degree Elevation Card. Include this card if RTYP =2 or 3.

Card 3	1	2	3	4	5	6	7	8
Variable	TR	TS						
Type	I	I						
Default	0	0						

VARIABLE	DESCRIPTION
TR	Target polynomial degree in the local r-direction; see Remark 1.
TS	Target polynomial degree in the local s-direction; see Remark 1.

Remarks:

1. **Polynomial degree reduction.** Polynomial degree reduction is not facilitated, meaning $\mathrm{TR} = \max[0, (\mathrm{TR} - \mathrm{PR})]$ and $\mathrm{TS} = \max[0, (\mathrm{TS} - \mathrm{PS})]$, where PR and PS designate the polynomial degree in the local *r*- and *s*-directions, respectively. See *IGA_2D_NURBS_XYZ keyword for more details.

*IGA_REFINE_SOLID

Purpose: Define refinement for isogeometric solids (see *IGA_SOLID). This capability is limited to solids parameterized by trivariate structured splines (see *IGA_VOLUME_-XYZ and *IGA_3D_NURBS_XYZ).

Card Summary:

Card 1. This card is required.

RID	RTYP						

Card 2. Include this card if RTYP = 1 or 2.

HRTYP	RR	RS	RT				

Card 3. Include this card if RTYP = 2 or 3.

TR	TS	TT					

Data Card Definitions:

Card 1	1	2	3	4	5	6	7	8
Variable	RID	RTYP						
Type	I	I						
Default	none	none						

VARIABLE	DESCRIPTION
RID	Isogeometric solid refinement ID. A unique number must be chosen.
RTYP	Refinement type: EQ.1: *h*-refinement (knot insertion) EQ.2: *k*-refinement, meaning *p*-refinement followed by *h*-refinement EQ.3: *p*-refinement (degree elevation)

Knot Insertion Card. Include this card if RTYP = 1 or 2.

Card 2	1	2	3	4	5	6	7	8
Variable	HRTYP	RR	RS	RT				
Type	I	F	F	F				
Default	none	none	none	none				

VARIABLE	DESCRIPTION
HRTYP	*h*-refinement type: EQ.1: Number of subdivisions-based. Each nonzero knot span is subdivided to NINT(RR) × NINT(RS) × NINT(RT) equal knot spans. Here, NINT(x) rounds x to the nearest whole integer. EQ.2: Physical length-based. Each nonzero knot span is subdivided such that the physical dimension of the resulting knot spans is about RR × RS × RT. See Remark 1.
RR	Knot refinement parameter in the local *r*-direction: HRTYP.EQ.1: NINT(RR) is the number of equal parametric segments in the local *r*-direction. NINT(RR) means the input RR is rounded to the nearest integer. HRTYP.EQ.2: RR is the approximate physical length of the resulting knot spans in the local *r*-direction.
RS	Knot refinement parameter in the local *s*-direction: HRTYP.EQ.1: NINT(RS) is the number of equal parametric segments in the local *s*-direction. NINT(RS) means the input RS is rounded to the nearest integer. HRTYP.EQ.2: RS is the approximate physical length of the resulting knot spans in the local *s*-direction.
RT	Knot refinement parameter in the local *t*-direction: HRTYP.EQ.1: NINT(RT) is the number of equal parametric segments in the local *t*-direction. NINT(RT) means the input RT is rounded to the nearest integer. HRTYP.EQ.2: RT is the approximate physical length of the

VARIABLE	DESCRIPTION
	resulting knot spans in the local t-direction.

Polynomial Degree Elevation Card. Include this card if RTYP = 2 or 3.

Card 3	1	2	3	4	5	6	7	8
Variable	TR	TS	TT					
Type	I	I	I					
Default	0	0	0					

VARIABLE	DESCRIPTION
TR	Target polynomial degree in the local r-direction; see Remark 2.
TS	Target polynomial degree in the local s-direction; see Remark 2.
TT	Target polynomial degree in the local t-direction; see Remark 2.

Remarks:

1. **Physical length-based refinement.** The approach is currently limited to the simplest trilinear parameterizations, meaning NR = NS = NT = 2 and PR = PS = PT = 1, where NR, NS, and NT denote the number of control points while PR, PS, and PT designate the polynomial degree in the local r-, s-, and t-directions, respectively. See *IGA_3D_NURBS_XYZ for more details.

2. **Polynomial degree reduction.** Polynomial degree reduction is not facilitated. Thus, $\mathrm{TR} = \max[0, (\mathrm{TR} - \mathrm{PR})]$, $\mathrm{TS} = \max[0, (\mathrm{TS} - \mathrm{PS})]$, and $\mathrm{TT} = \max[0, (\mathrm{TT} - \mathrm{PT})]$, where PR, PS, and PT designate the polynomial degree in the local r-, s-, and t-directions, respectively. See *IGA_3D_NURBS_XYZfor more details.

*IGA_SHELL

Purpose: Define a set of isogeometric shell elements.

Card 1	1	2	3	4	5	6	7	8
Variable	SID	PID	NISR	NISS	RID		IDFNE	
Type	I	I	F	F	I		I	
Default	none	none	0.	0.	0		0	

VARIABLE	DESCRIPTION
SID	Isogeometric shell (patch) ID; see Remarks 1 and 2. A unique number must be chosen.
PID	Part ID
NISR	Interpolation elements in the local r-direction (see Remark 3): LT.0.0: |NISR| is the average edge length of the interpolation elements in the local r-direction. EQ.0.0: The number of interpolation elements per isogeometric element is equal to the polynomial degree in the local r-direction. GT.0.0: Number of interpolation elements per isogeometric element in the local r-direction. NISR must be an integer.
NISS	Interpolation elements in the local s-direction (see Remark 3): LT.0.0: |NISS| is the average edge length of the interpolation elements in the local s-direction. EQ.0.0: The number of interpolation elements per isogeometric element is equal to the polynomial degree in the local s-direction. GT.0.0: Number of interpolation elements per isogeometric element in the local s-direction. NISS must be an integer.
RID	Shell refinement ID. See *IGA_REFINE_SHELL.
IDFNE	Element ID of the first IGA element (knot span) within this isogeometric shell (patch) definition

Remarks:

1. **Discretized shells.** A shell ID is a physical face ID; see *IGA_FACE_XYZ.

2. **Mass matrix.** Like the standard convention in the structural solver, the row sum mass matrix formulation is invoked by default. A consistent mass matrix may be used at the model level by invoking the *CONTROL_IMPLICIT_CONSISTENT_MASS keyword.

3. **Interpolation elements.** Contact treatment and post-processing are presently dealt with interpolation elements defined by interpolation nodes. These nodes and elements are automatically created.

*IGA_SOLID

Purpose: Define a set of isogeometric solid elements.

Card 1	1	2	3	4	5	6	7	8
Variable	SID	PID	NISR	NISS	NIST	RID		
Type	I	I	F	F	F	I		
Default	none	none	0.	0.	0.	0		

VARIABLE	DESCRIPTION
SID	Isogeometric solid (patch) ID; see Remarks 1 and 2. A unique number must be chosen.
PID	Part ID
NISR	Interpolation elements in the local *r*-direction (see Remark 3): LT.0.0: |NISR| is the average edge length of the interpolation elements in the local *r*-direction. EQ.0.0: The number of interpolation elements per isogeometric element is equal to the polynomial degree in the local *r*-direction. GT.0.0: Number of interpolation elements per isogeometric element in the local *r*-direction. NISR must be an integer.
NISS	Interpolation elements in the local *s*-direction (see Remark 3): LT.0.0: |NISS| is the average edge length of the interpolation elements in the local *s*-direction. EQ.0.0: The number of interpolation elements per isogeometric element is equal to the polynomial degree in the local *s*-direction. GT.0.0: Number of interpolation elements per isogeometric element in the local *s*-direction. NISS must be an integer.
NIST	Interpolation elements in the local *t*-direction (see Remark 3): LT.0.0: |NIST| is the average edge length of the interpolation elements in the local *t*-direction.

VARIABLE	DESCRIPTION
	EQ.0.0: The number of interpolation elements per isogeometric element is equal to the polynomial degree in the local t-direction.
	GT.0.0: Number of interpolation elements per isogeometric element in the local t-direction. NIST must be an integer.
RID	Solid refinement ID. See *IGA_REFINE_SOLID.

Remarks:

1. **Discretized solids.** A solid ID is a physical volume ID; see *IGA_VOLUME_XYZ.

2. **Mass matrix.** Similar to the standard convention in the structural solver, the row sum mass matrix formulation is invoked by default. A consistent mass matrix may be used at the model level by invoking the *CONTROL_IMPLICIT_CONSISTENT_MASS keyword.

3. **Interpolation elements.** Contact treatment and post-processing are presently dealt with interpolation elements defined by interpolation nodes. These nodes and elements are automatically created.

*IGA_TIED_EDGE_TO_EDGE

Purpose: Mechanically couple entities along topologically connected edges. The topology is given implicitly using the relation between parametric and physical edges; see *IGA_EDGE_UVW and *IGA_EDGE_XYZ.

Card 1	1	2	3	4	5	6	7	8
Variable	ID	TYPE	FORM	SFD	SFR	SFT		
Type	I	I	I	F	F	F		
Default	0	0	0	1.0	1.0	1.0		

VARIABLE	DESCRIPTION
ID	Apply coupling to entities referenced by the ID field along topologically connected edges. The next field, TYPE, specifies the type of entity to which ID refers because entities of different kinds, such as parts and part sets, are not uniquely numbered. Currently (as of June 2020), Currently, no types requiring an ID are supported. This field is reserved for future enhancements.
TYPE	Type of ID: EQ.0: Include all topological connections in the model. No ID required.
FORM	Coupling formulation: EQ.0: Penalty-based tied contact
SFD	Scaling factor for displacement penalty stiffness
SFR	Scaling factor for rotational penalty stiffness
SFT	Scaling factor for thin constraint penalty stiffness (rotation free elements)

*IGA_VOLUME_XYZ_{OPTION}

Purpose: Define a physical volume, that is, a physical trivariate non-uniform rational B-spline (NURBS) or a physical trivariate basis transform. A physical volume is used to define isogeometric solids (see *IGA_SOLID) as well as boundary conditions and/or constraints on its (sub)volume.

Available options include:

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BASIS_TRANSFORM

Card Summary:

Card 1. This card is required.

VID	PATCHID	PSID	ESID	FSID			

Card 2. Include this card if no keyword option is used. Include as many cards in the following format as desired. This input ends at the next keyword ("*") card.

BRID1	BRID2	BRID3	BRID4	BRID5	BRID6	BRID7	BRID8

Data Card Definitions:

Card 1	1	2	3	4	5	6	7	8
Variable	VID	PATCHID	PSID	ESID	FSID			
Type	I	I	I	I	I			
Default	none	none	none	none	none			

VARIABLE	DESCRIPTION
VID	Parametric volume ID. A unique number must be chosen.
PATCHID	Depending on the keyword option either a physical trivariate NURBS patch ID for no keyword option (see *IGA_3D_NURBS_XYZ) or a trivariate basis transform patch ID for the BASIS_TRANSFORM keyword option (see *IGA_3D_BASIS_TRANSFORM_XYZ).

VARIABLE	DESCRIPTION
PSID	Parametric point set ID; see *IGA_POINT_UVW and *SET_IGA_-POINT_UVW. See Remark 2.
ESID	Parametric edge set ID; see *IGA_EDGE_UVW and *SET_IGA_-EDGE_UVW. See Remark 2.
FSID	Parametric face set ID; see *IGA_FACE_UVW and *SET_IGA_-FACE_UVW. See Remark 2.

Boundary Representation Cards. Include boundary representations defining the physical volume, see Remark 1. This input ends at the next keyword ("*") card.

Card 2	1	2	3	4	5	6	7	8
Variable	BRID1	BRID2	BRID3	BRID4	BRID5	BRID6	BRID7	BRID8
Type	I	I	I	I	I	I	I	I
Default	none	none	none	none	none	none	none	none

VARIABLE	DESCRIPTION
BRID*i*	Two-dimensional boundary representation IDs (see *IGA_2D_-BREP) with $i = 1, \ldots, n$ and $n > 0$.

Remarks:

1. **Topology.** To establish topological relations among physical volumes, at least a single boundary representation must be included.

2. **Dependent parametric object sets.** The collection of parametric points, edges, and faces identifies, in the topological sense, reduced subsets of the underlying trivariate NURBS parameterization. These reduced subsets are used in boundary conditions and/or constraint definitions.