IMPACT DAMAGE IN COMPOSITE PLATES

BY

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INTRODUCTION

Computer Code: PDCOMP

Progressive damage analysis for laminated composites.

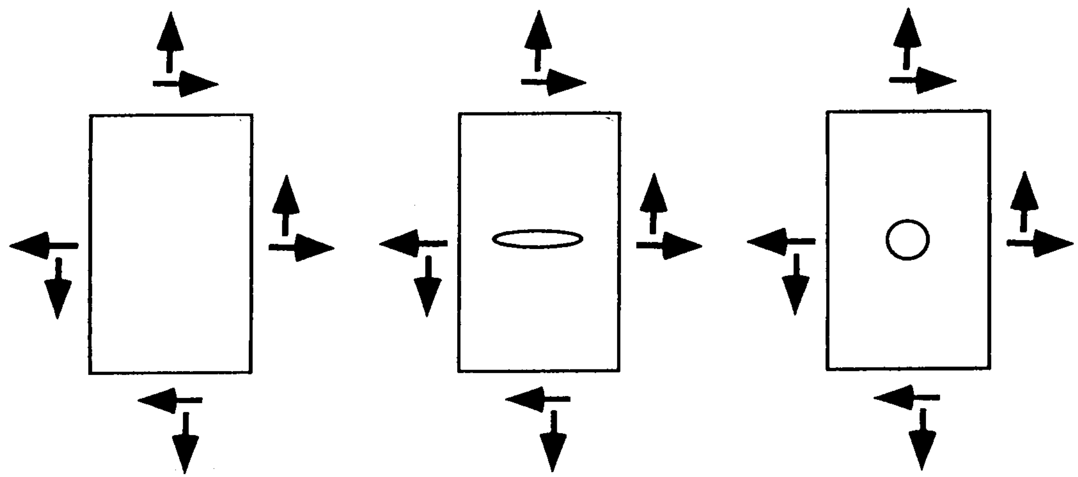
Ref: Shahid and Chang," An accumulative damage model for tensile and shear failures of laminated composite plates" (1994, JCM).

Computer Code: 3DIMPACT

Prediction of the extent of delaminations in laminated composites resulting from a point impact load.

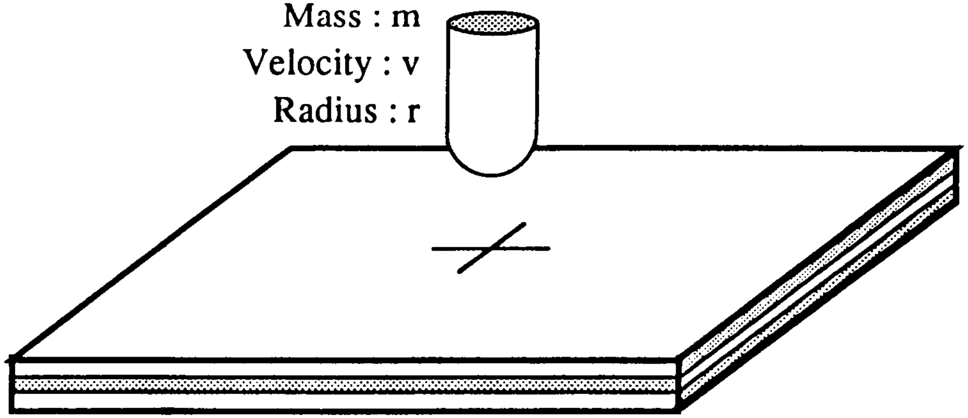
Ref: Choi and Chang, "A model for predicting impact damage of graphite/epoxy laminated composites due to point-nose impact" (1992, JCM).

PDCOMP CODE



- Predict damage accumulated inside composites as a function of applied loads.
- Estimate residual ply properties as a function of damage state and failure mode.
- Limited to symmetric laminates.
- Ignore the edge effect.

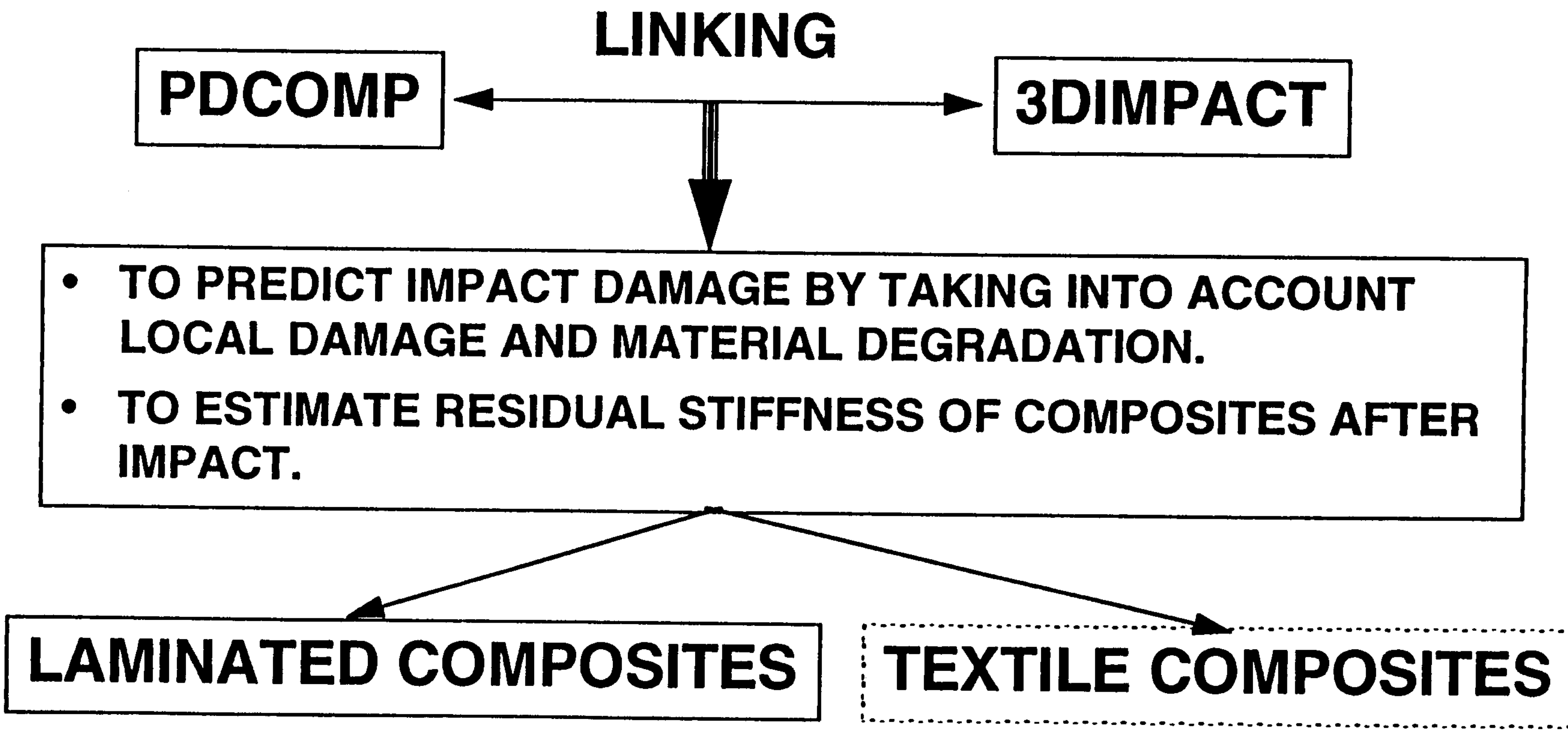
3DIMPACT CODE



Laminated Composite Plate

- Predict impact velocity threshold.
- Estimate the extent of delaminations in laminates resulting from low-velocity impact.
- Limited to symmetric laminates.
- Applied to point-nose impact.
- No material degradation considered.
- Needs to determine an empirical parameter Da.

OBJECTIVE


LINKING
PDCOMP
3DIMPACT
• TO PREDICT IMPACT DAMAGE BY TAKING INTO ACCOUNT LOCAL DAMAGE AND MATERIAL DEGRADATION.
• TO ESTIMATE RESIDUAL STIFFNESS OF COMPOSITES AFTER IMPACT.
LAMINATED COMPOSITES
TEXTILE COMPOSITES

MAJOR MODIFICATION OF THE 3DIMPACT CODE

FOR LAMINATED COMPOSITES

1. Failure Criteria

   matrix cracking

   delamination

   fiber breakage

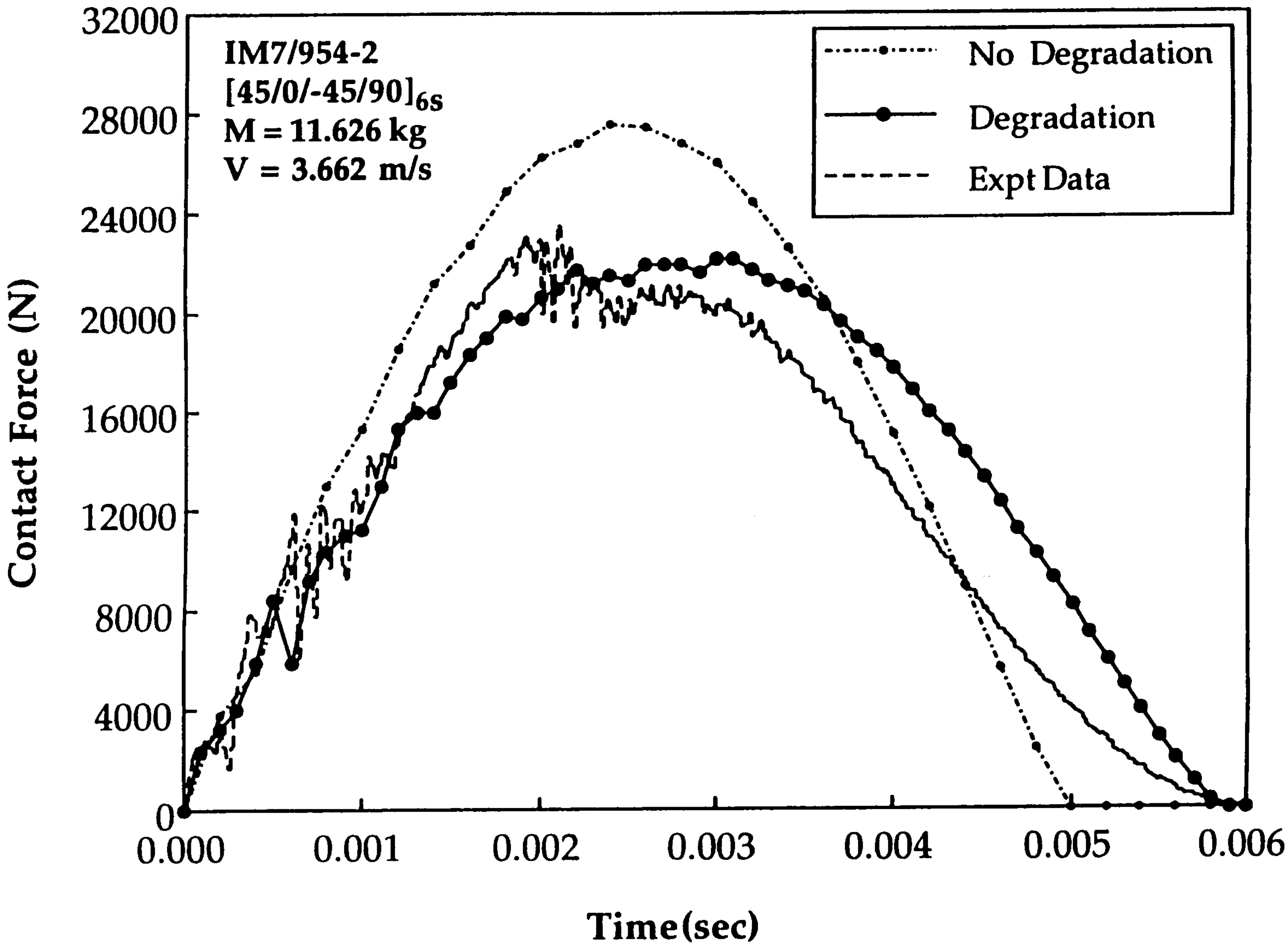
2. Material Degradation

   - Material properties as a function of failure mode and the extent of the damage (from PDCOMP).

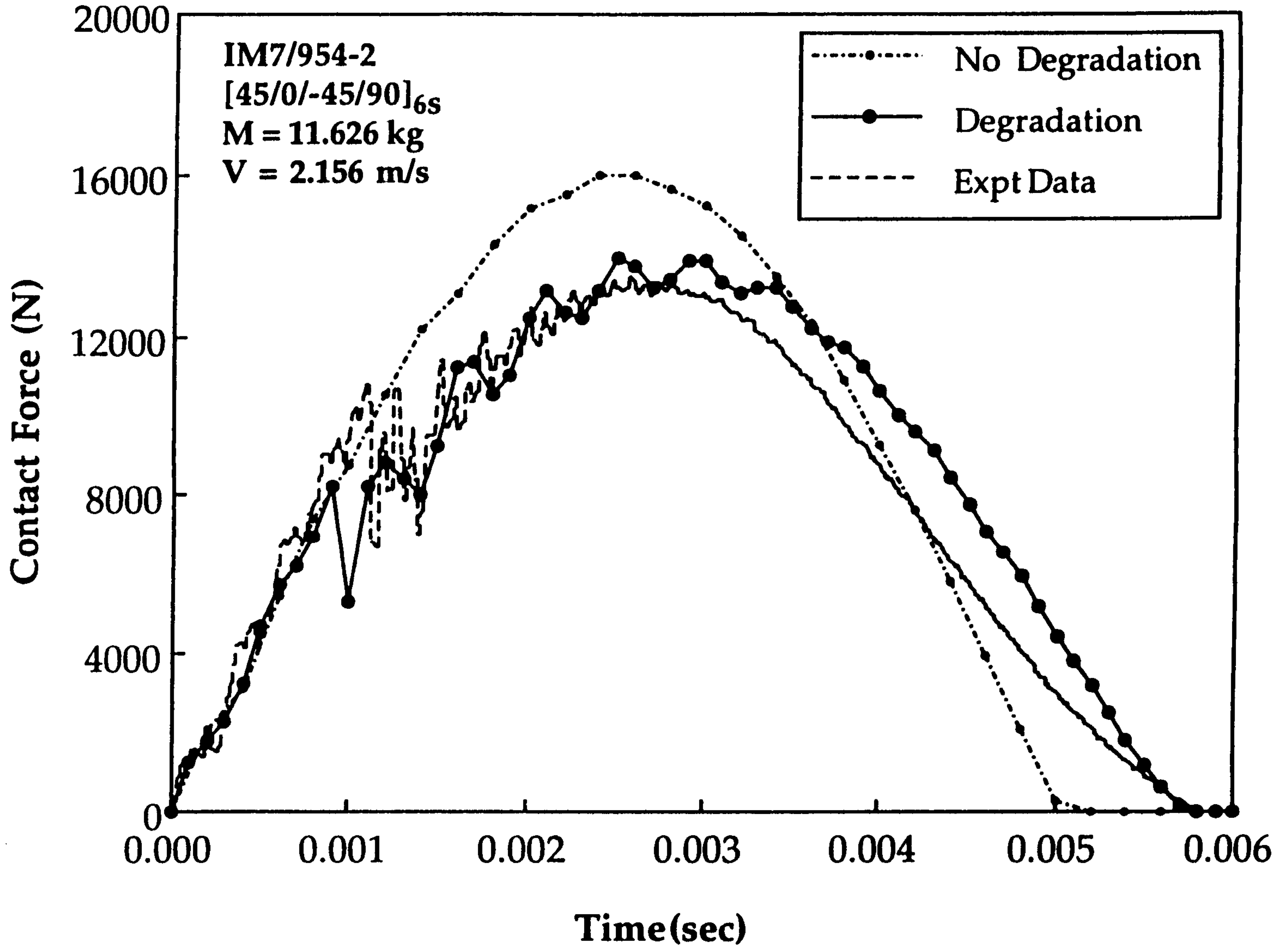
3. Hertzian Contact Law ($F = k \alpha^{\beta}$)

   - Modify contact stiffness k as a function of damaged material properties.
   - Apply to both loading and unloading paths.
   - Contact area may vary during impact.

LOCAL DAMAGE EFFECT ON FORCE RESPONSE



Impact force distribution as a function of time for IM7/954-2 graphite/epoxy composites. Comparison between the predictions with and without material degradation and the test data.



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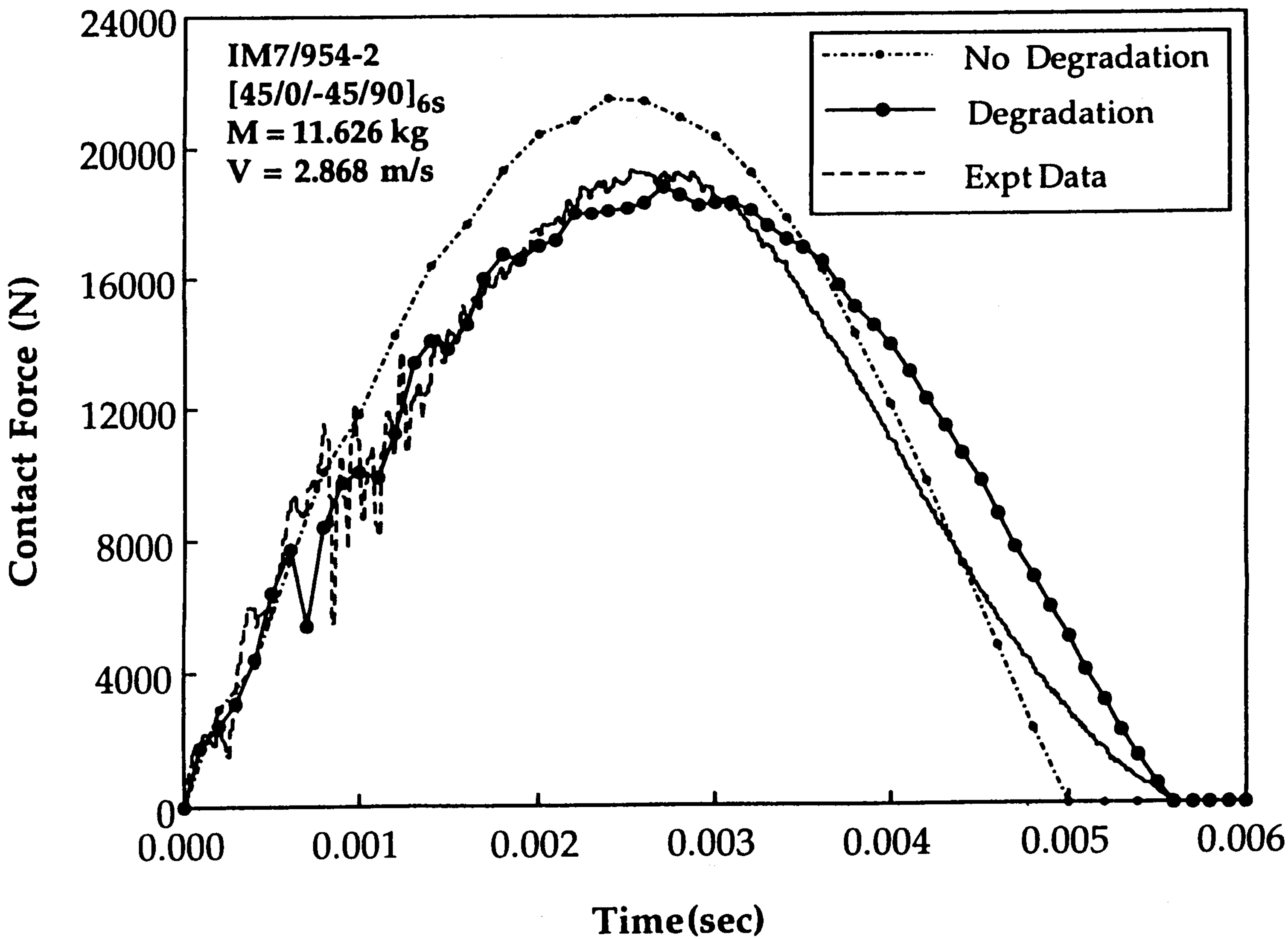

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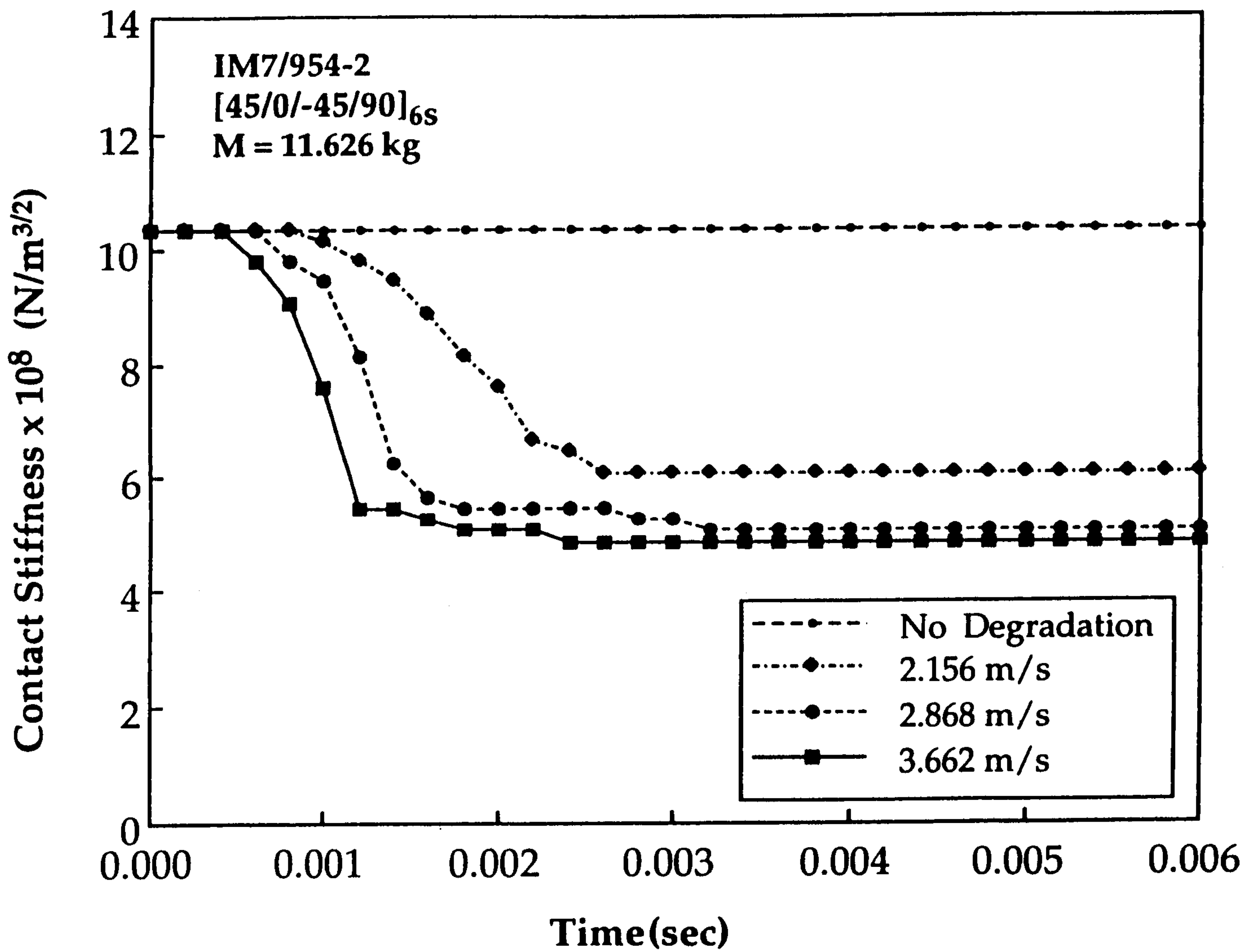
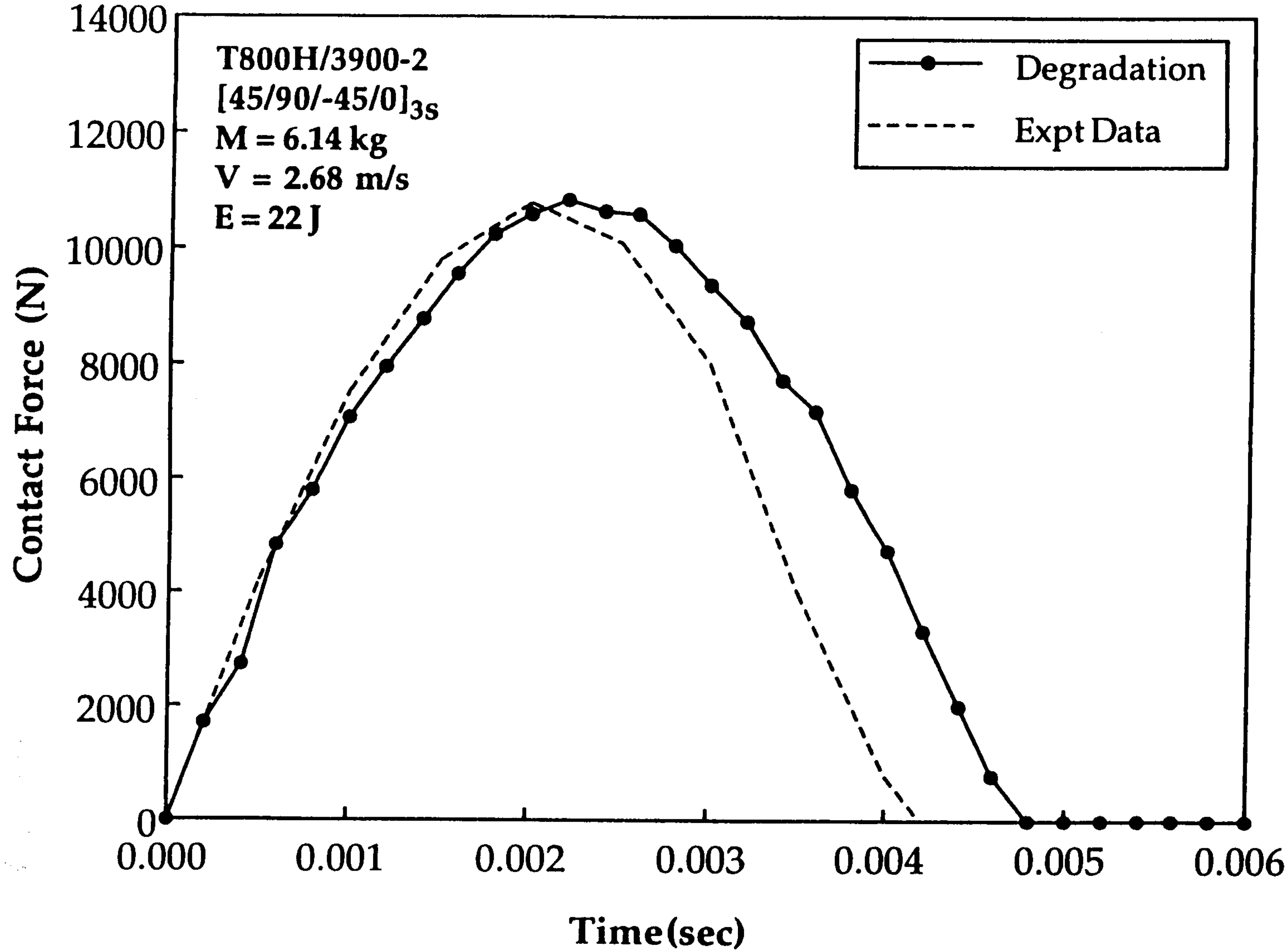
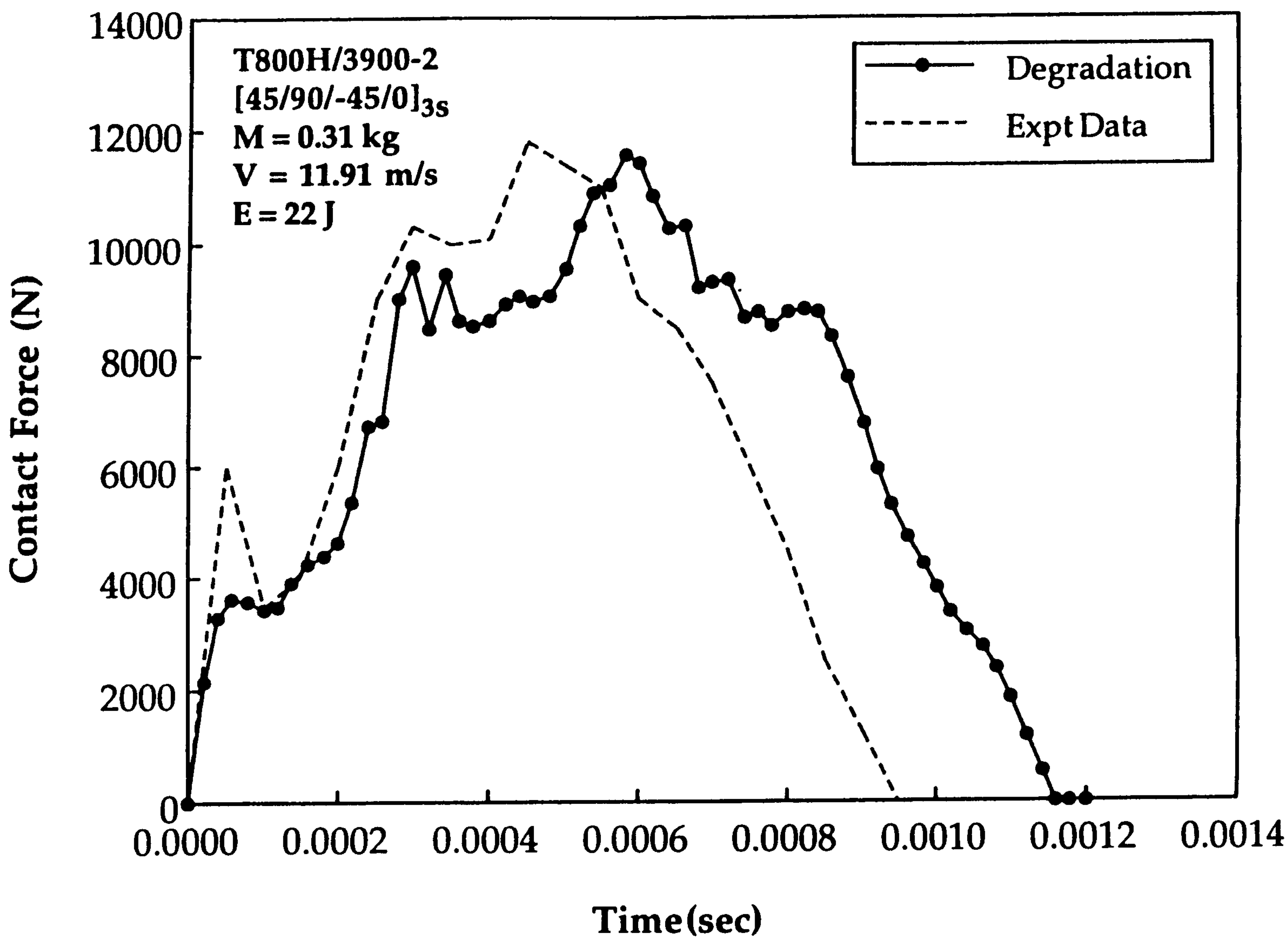


The distribution of the contact stiffness as a function of time during impact on IM7/954-2 graphite/epoxy composites for an impactor at three different velocities.

MASS EFFECT (AT SAME IMPACT ENERGY)



Impact force distribution as a function of time for T800/3900-2 graphite/epoxy composites. Comparison between the predictions based on the present model and the test data



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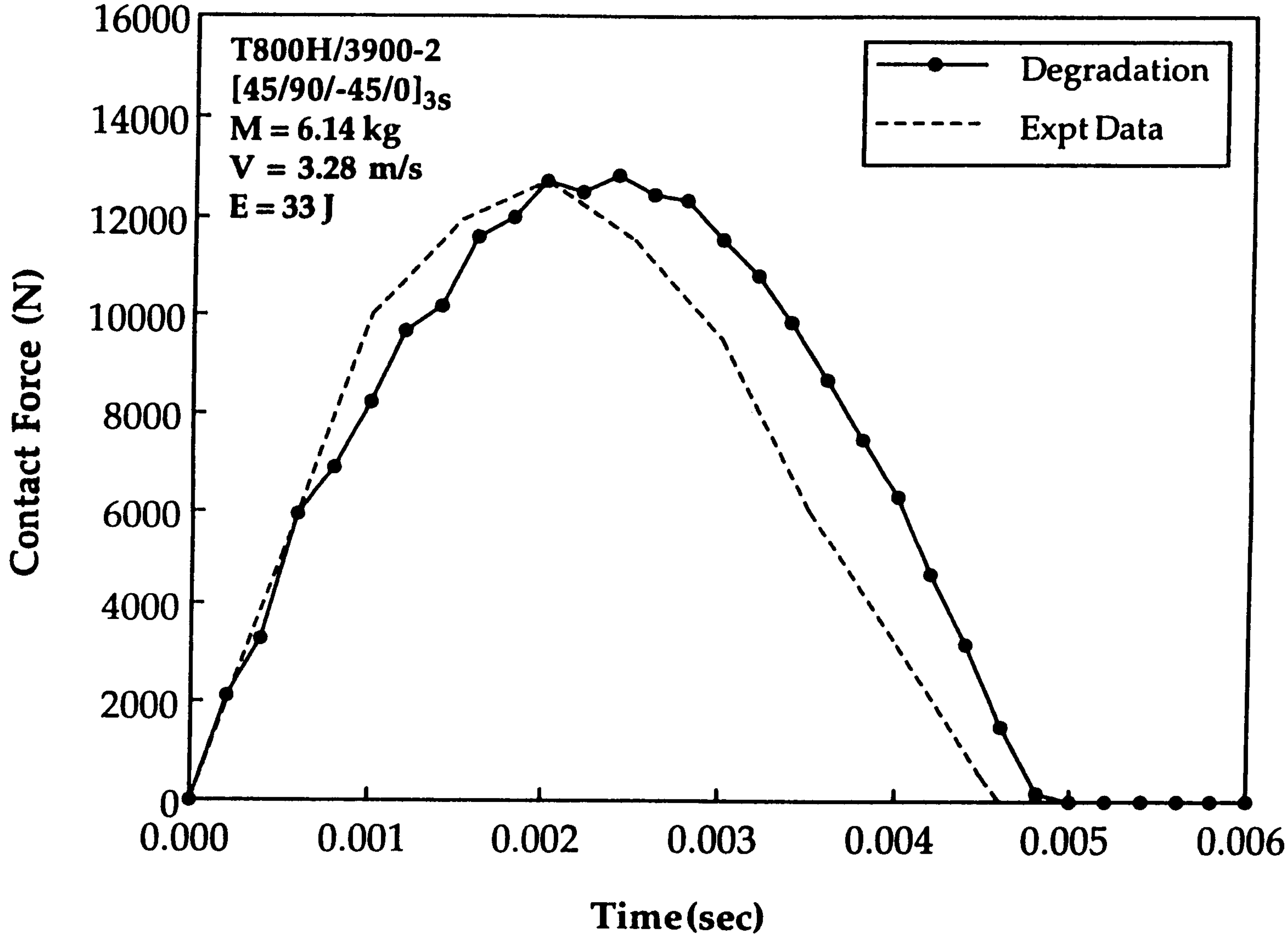

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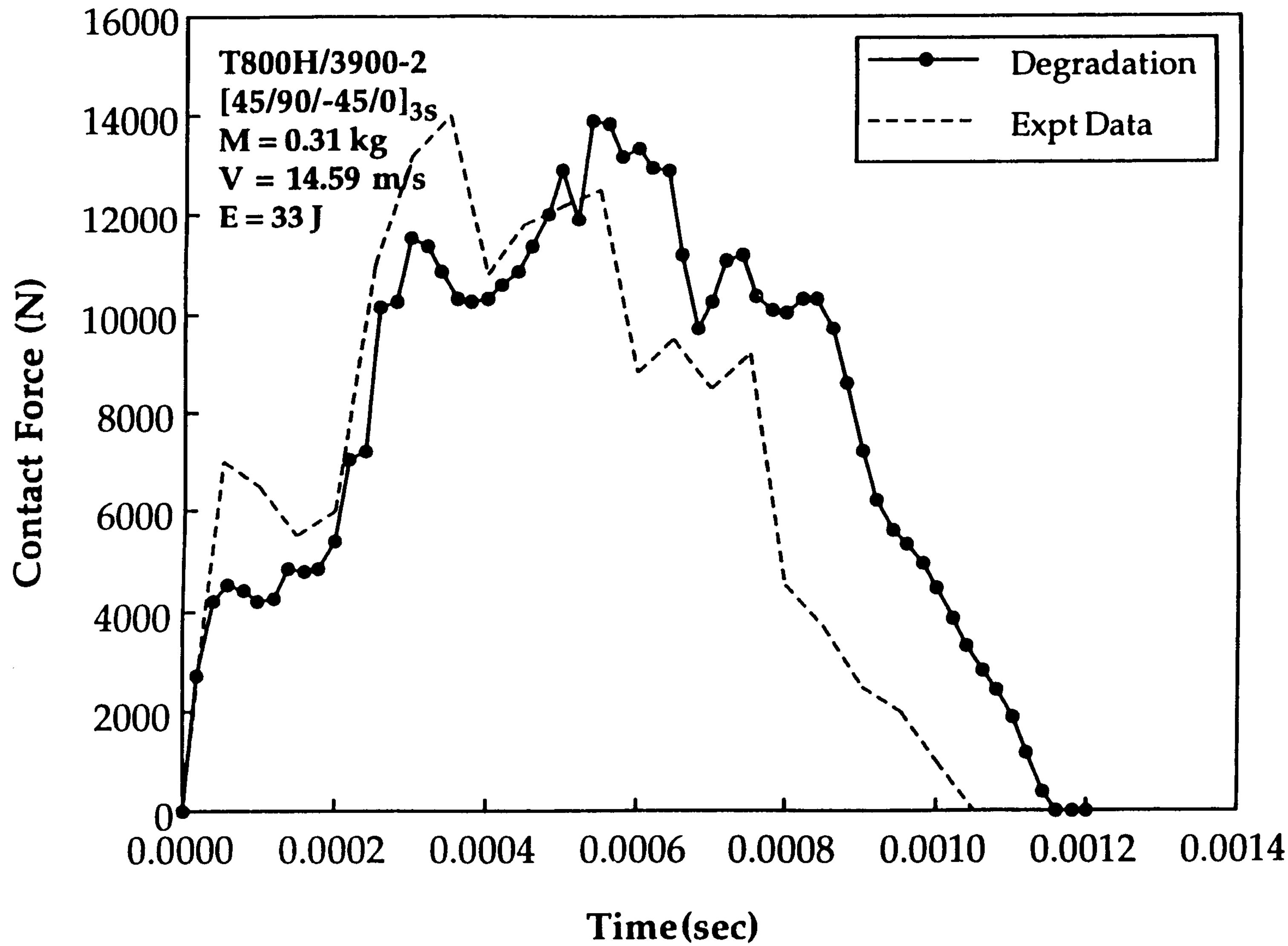
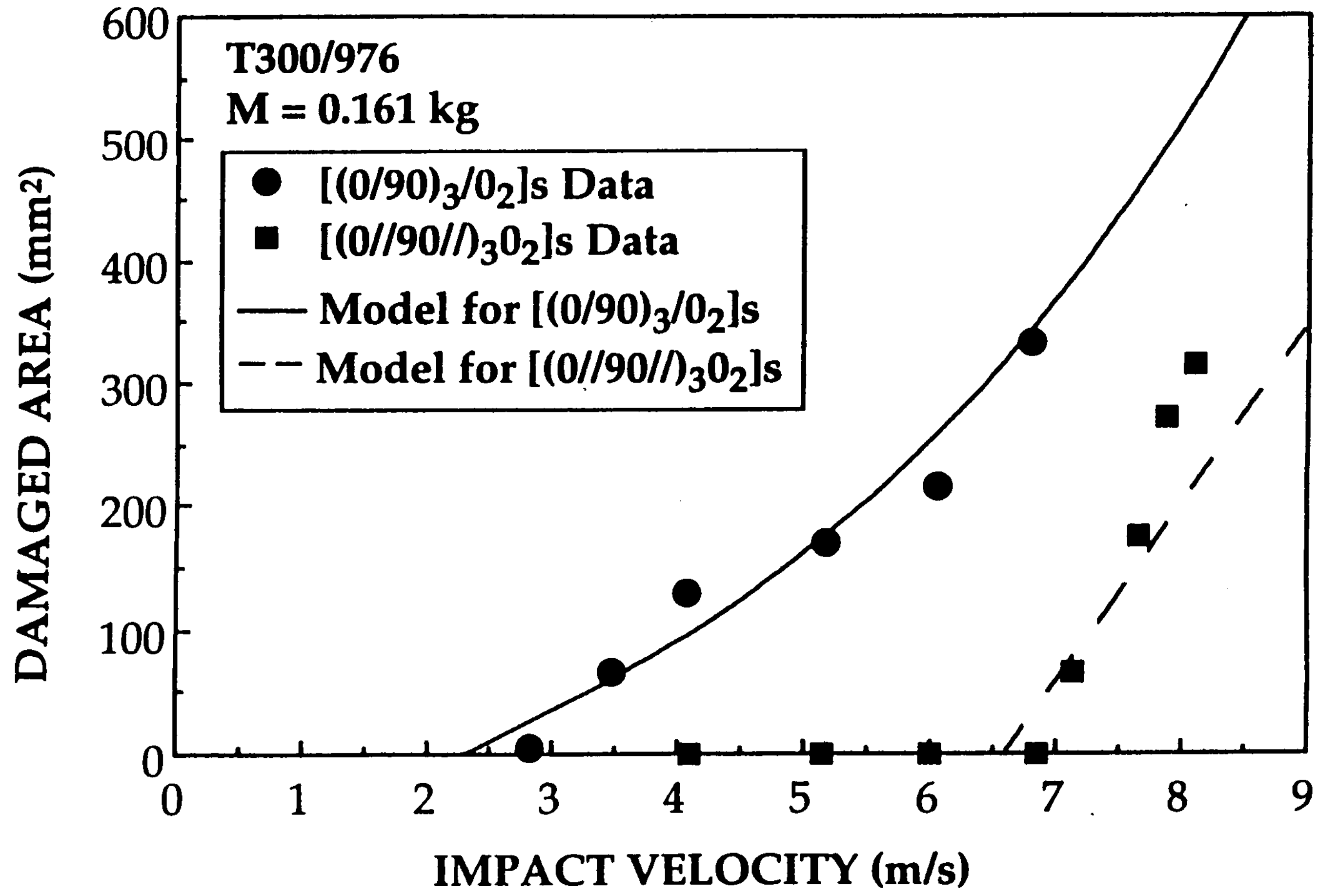
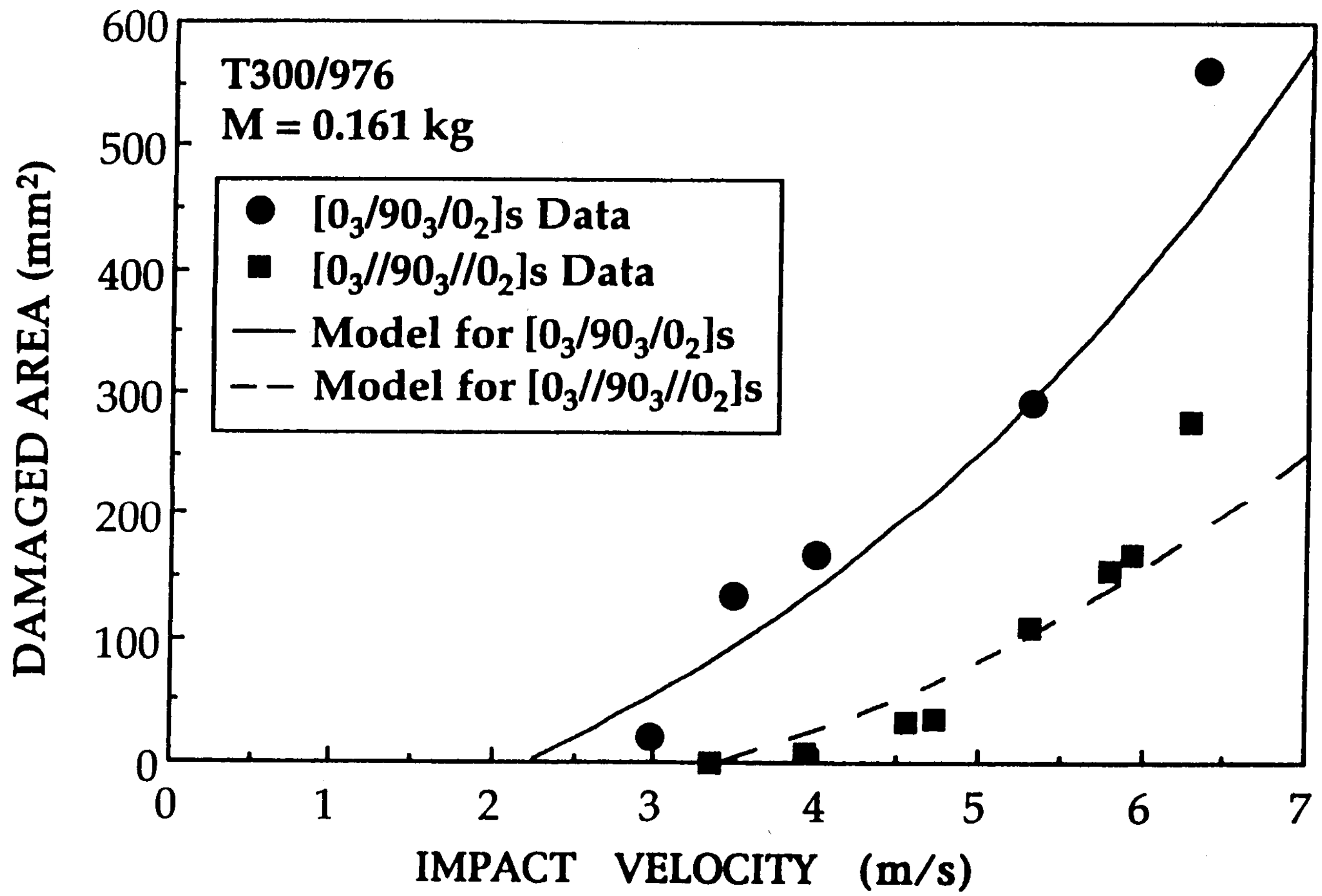


Impact force distribution as a function of time for T800/3900-2 graphite/epoxy composites. Comparison between the predictions based on the present model and the test data

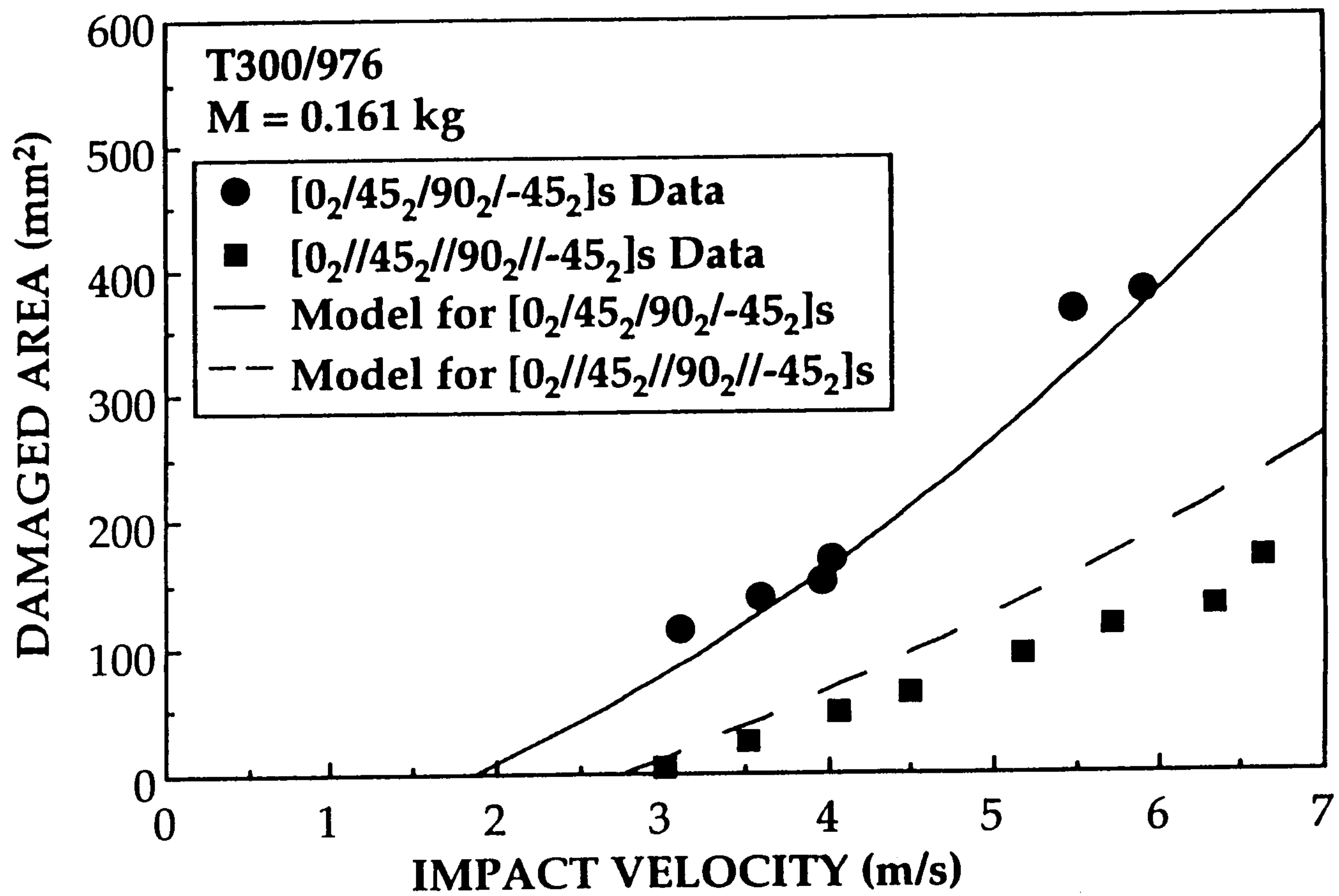
INTERFACIAL STRENGTH EFFECT
(WITH AND WITHOUT INTERLEAVES)



Impact damage area as a function of the impact velocity for composites with and without interleaves. Comparison between the predictions and the test data.



Impact damage area as a function of the impact velocity for composites with and without interleaves. Comparison between the predictions and the test data.



Impact damage area as a function of the impact velocity for composites with and without interleaves. Comparison between the predictions and the test data.

THE MAJOR INCLUSION IN 3DIMPACT CODE

FOR TEXTILE COMPOSITES

1. **Material Properties**
   - Homogeneous and anisotropic media
2. **Failure Criteria**
   - Modified Tsai-Wu 3-D failure criterion

     Mode I: inplane failure dominated along a principal axis

     Mode II: inplane failure dominated along the second principal axis.

     Model III: out-of-plane failure.
3. **Material Degradation**
   - Material properties as a function of failure mode; a 0.1 degradation factor applied to the engineering properties associated with the failure mode.
4. **Modified Hertzian Contact Law ($F = (k)\,\alpha^{\beta}$)**

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Impact and CAI test conditions

Code	Material Form	Pattern	Laminate Thickness (in.)	Ply Thickness (in.)	Impact Energy (in.-lb)
L1	Braids	2	0.151	0.0377	146
L2	"	1	0.165	0.0413	146
L3	Woven(LTL)	2	0.162	0.0405	146
L4	"	1	0.162	0.0405	146
L5	Woven(TTT)	2	0.171	0.0425	146
L6	Braids	2	0.175	0.0437	240
L7	"	1	0.161	0.0403	240
L8	Woven(LTL)	2	0.164	0.041	240
L9	"	1	0.165	0.0413	240
L10	Woven(TTT)	2	0.169	0.0422	240
N1*	Braids	1	0.181	0.0453	240
N2*	"	1	0.172	0.043	192
N3*	"	1	0.178	0.0445	72
N4*	"	1	0.179	0.0447	96
N5*	Woven(LTL)	1	0.175	0.0437	72
N6*	"	1	0.168	0.042	96
N7*	"	1	0.173	0.0432	240

Impactor mass 13.2 lbf; * 9.8 lbf. ; Nose radius 5/16 in.

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MATERIAL PROPERTIES USED IN THE CALCULATIONS

Impactor	velocity(in/s)	Exx(msi)	Eyy(msi)	Ezz(msi)	Vxy	Vxz	Vyz	Gxy(msi)	Gxz(msi)	Gyz(msi)	Xt (ksi)	Yt (ksi)
1	92.43	11.180	4.420	4.420	0.4000	0.4000	0.5700	1.630	1.630	1.578	104.34	29.11
2	92.43	7.410	4.380	4.380	0.3920	0.3920	0.5600	2.170	2.170	1.573	80.94	55.48
3	92.43	11.420	10.040	1.575	0.0528	0.4778	0.3892	0.976	1.743	1.250	102.31	90.41
4	92.43	10.820	9.843	1.544	0.0515	0.4813	0.3761	0.937	1.852	1.227	123.04	83.56
5	92.43	10.710	9.995	1.523	0.0578	0.4094	0.3711	0.910	1.450	1.207	108.47	93.45
6												
7	118.51	11.180	4.420	4.420	0.4000	0.4000	0.5700	1.630	1.630	1.578	104.34	29.11
8	118.51	7.410	4.380	4.380	0.3920	0.3920	0.5600	2.170	2.170	1.573	80.94	55.48
9	118.51	11.420	10.040	1.575	0.0528	0.4778	0.3892	0.976	1.743	1.250	102.31	90.41
10	118.51	10.820	9.843	1.544	0.0515	0.4813	0.3761	0.937	1.852	1.227	123.04	83.56
11	118.51	10.710	9.995	1.523	0.0578	0.4094	0.3711	0.910	1.450	1.207	108.47	93.45
12												
13	137.54	7.410	4.380	4.380	0.3920	0.3920	0.5600	2.170	2.170	1.573	80.94	55.48
14	123.00	7.410	4.380	4.380	0.3920	0.3920	0.5600	2.170	2.170	1.573	80.94	55.48
15	75.36	7.410	4.380	4.380	0.3920	0.3920	0.5600	2.170	2.170	1.573	80.94	55.48
16	87.00	7.410	4.380	4.380	0.3920	0.3920	0.5600	2.170	2.170	1.573	80.94	55.48
17												
18	75.36	10.820	9.843	1.544	0.0515	0.4813	0.3761	0.937	1.852	1.227	123.04	83.56
19	87.00	10.820	9.843	1.544	0.0515	0.4813	0.3761	0.937	1.852	1.227	123.04	83.56
20	137.52	10.820	9.843	1.544	0.0515	0.4813	0.3761	0.937	1.852	1.227	123.04	83.56

	Xc (ksi)	Yc (ksi)	Rail S (ksi)	Interlaminar Tension (ksi)
1	71.84	32.75	23.60	7.65
2	71.11	54.29	24.40	6.85
3	71.94	55.25	13.10	5.15
4	81.56	53.66	12.30	5.36
5	75.06	57.86	18.90	3.70
6				
7	71.84	32.75	23.60	7.65
8	71.11	54.29	24.40	6.85
9	71.94	55.25	13.10	5.15
10	81.56	53.66	12.30	5.36
11	75.06	57.86	18.90	3.70
12				
13	71.11	54.29	24.40	6.85
14	71.11	54.29	24.40	6.85
15	71.11	54.29	24.40	6.85
16	71.11	54.29	24.40	6.85
17				
18	81.56	53.66	12.30	5.36
19	81.56	53.66	12.30	5.36
20	81.56	53.66	12.30	5.36

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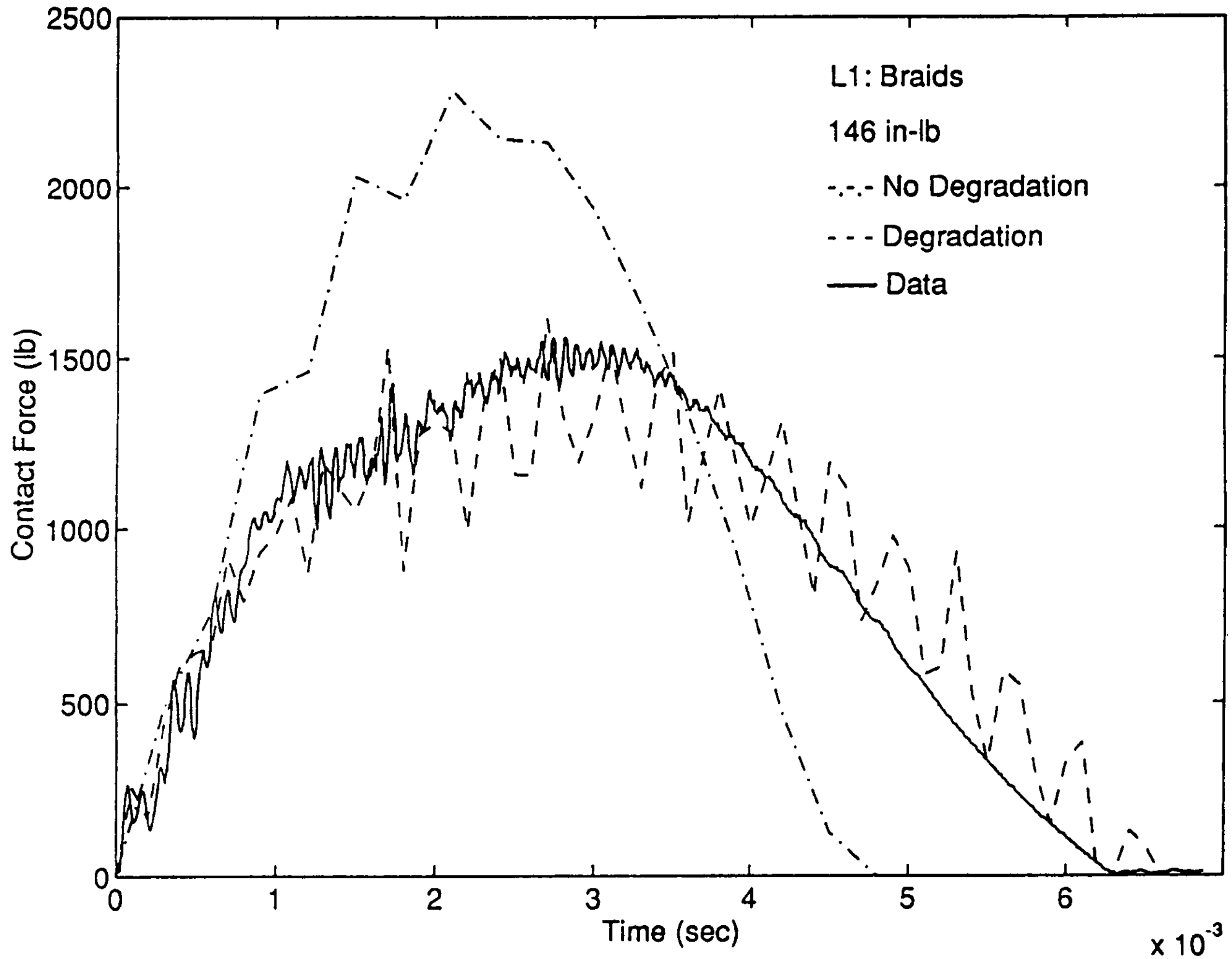

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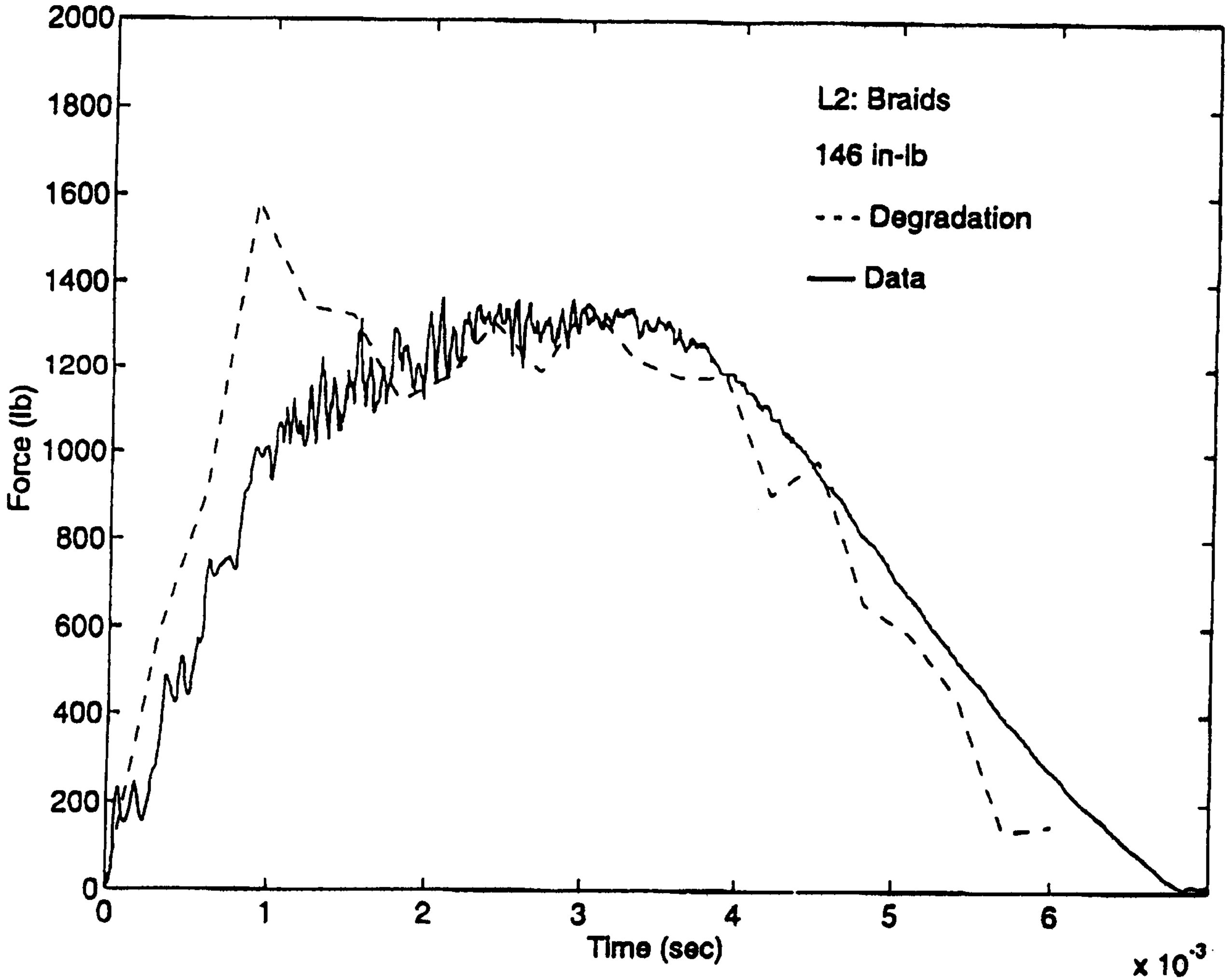

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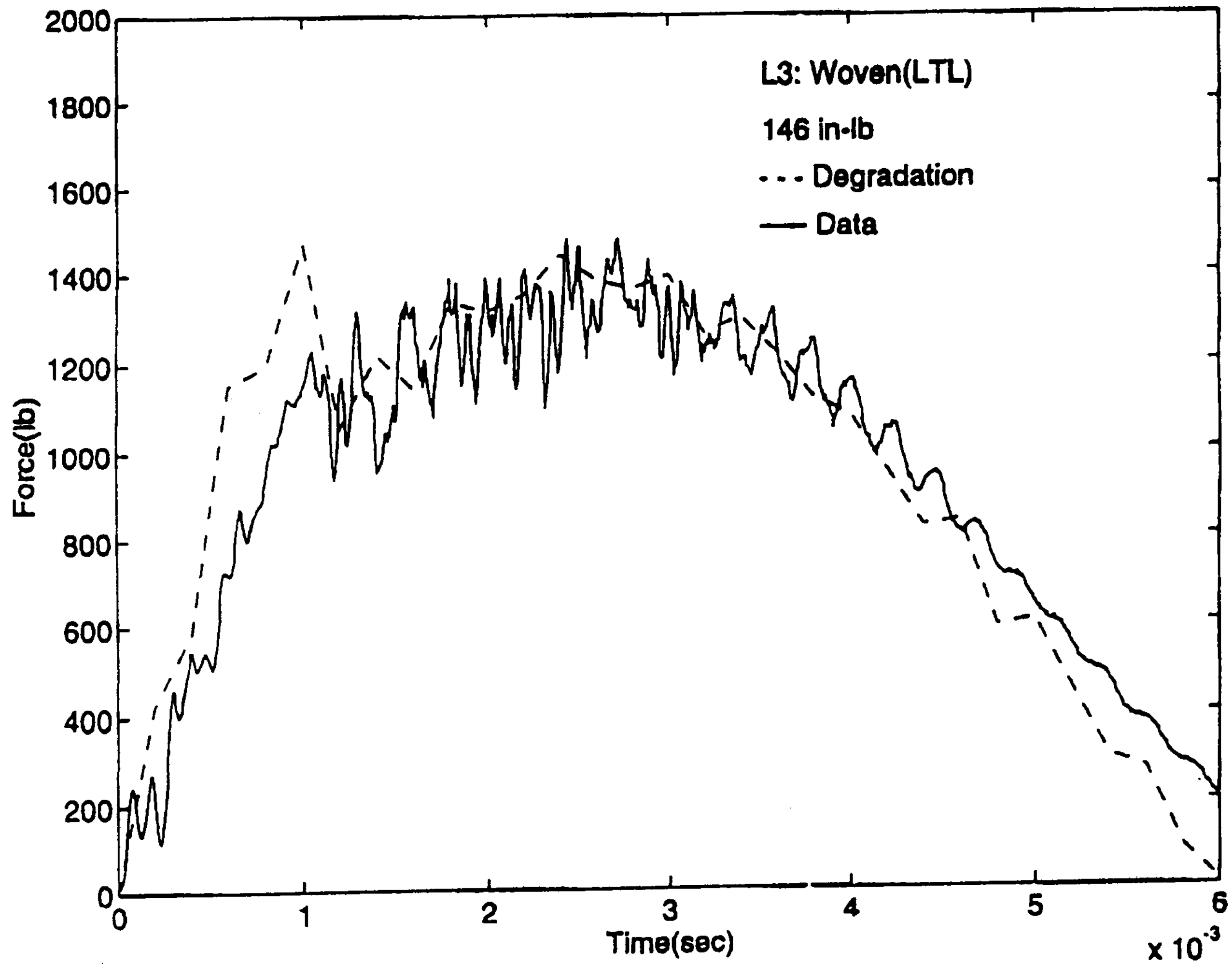

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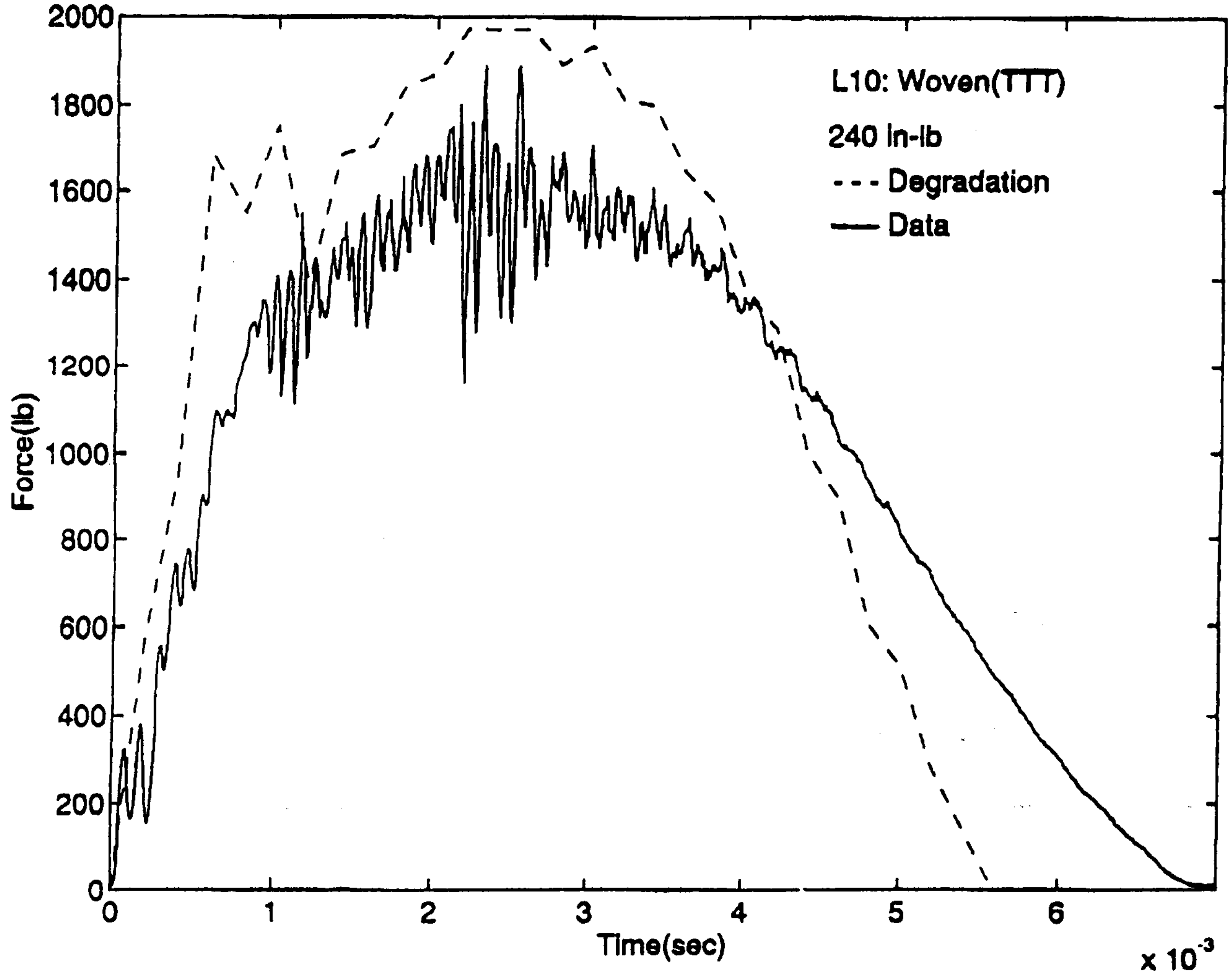

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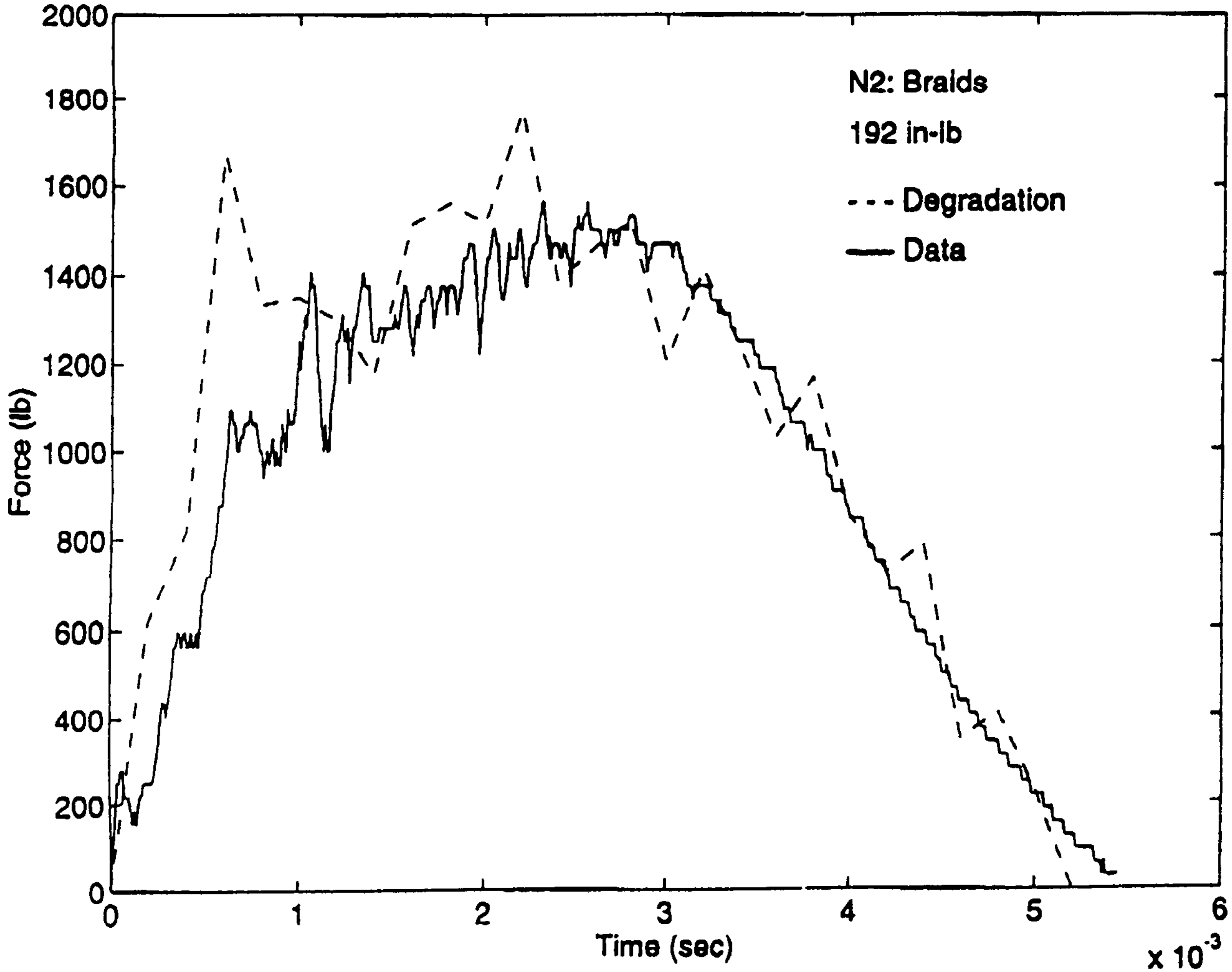

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Results Comparison - Analysis vs. Test

Code	Expt.Dent Depth(in.)	Pred. Dent Depth (in)	Damage Area(sq.in.)	Pred. Damage (sq. in.)	Expt. CAI (kips)	Pred. CAI (kips)
L1	0.011	0.026	0.99	1.196	29.8	23.5
L2	0.011		0.95		23.9	
L3	0.012	0.023	0.89	0.7	22.8	27.5
L4	0.015	0.024	1.13	0.551	23.5	13.5
L5	0.012	0.019	1.67	0.504	26.8	23.5
L6	0.014		1.67		26.2	
L7	0.058		1.35		19.1	
L8	0.018	0.029	1.42	0.74	21.2	16.5
L9	0.023	0.037	1.82	0.71	23.5	23
L10	0.023	0.025	2.24	0.627	26.3	22.5

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CONCLUSION

- The modified 3DIMPACT code could predict more accurately the impact damage in laminated composites than the earlier version.
- Local damage could have a significant effect on the response of the target and the force-time history of the impactor.
- The predictions of the code for textile composites were promising.
- More work needs to be done on characterization of material properties of textile composites containing damage.
- Hertzian contact law is not good for unloading and for simulating impact damage; the impactor should be included in the finite element modeling.