Predictive Model of Orthotropic Un-Symmetric Box Cam Based On Deflection And countered by Segments of Circular-Arc Contact Profiles

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Abstract

In this paper the principal objective is to find the deflection of orthotropic box cam profile countered by segments of circular-arc due to the effect of contact loading which produce the generate force that induces high contact stress on the cam-surface especially in high-speed machine. In highspeed it can be used the composite cam, since it affects the whole machine performance to improve the wear resistance. Several researchers investigated the effects of cam profile in accuracy and system flexibility on the output motion experimentally; but there is a lake in the theoretical part. The theoretical part has been done with the solution of orthotropic circular plate equation using the harmonic deflection motion of the follower. The cam used in this paper can be seen in composite shifter cam for a motorcycle transmission, composite hollow cam-shafts, the running valve lift with roller followers of a composite camshaft, and heavy duty of marine engine. The aim of the present paper is to find the maximum deflection of orthotropic box cam on the boundaries of the three circular-arc contact profiles for flanks and noses of contact follower loadings. The results were arrangement into theoretical part and finite element using software ANSYS 12.1.

Index terms— Orthotropic Cam, Contact Loading, Circular Plate Equation, ANSYS Software, Un-Symmetric Pressure Angles, Box Cam.

1 NOMENCLATURES

2 INTRODUCTION

new type of composite cam-shafts that obtain an optimum condition valve lift running with roller followers based on it a new composite function cam profile emphatically is developed, in most cases the lobe profile needs to have a concave form (negative radii in the area of the cam lift profile) to improve fullness coefficient, positive and negative peak acceleration and cam-follower contact stress in cam tip; but at the same time the conventional grinding equipment is to suitable to manufacture this type of cam profile, [1,2].Moreover the mechanical and microstructure properties of camshafts surfaces like Brinell, Rockwell, and Vickers hardness tests of Ti Al N/Al N composite film deposited on the profile surface of cam (made of chilled cast iron 45 steel) experimentally and numerically relating with the Ion Beam sputtering deposition, the solidification, and cooling rate technologies, in which the operation temperature can be controlled below the limitation of phases exchanging or at room temperature to avoid phase exchanging deformation and examined the rapid and slow cooling surfaces, rosette like graphite in pearlitic and low ferrite phase on cam hardness to improve the shape and dimension accuracy, [3,4].In the other hand the cam material (ferrous P/M materials) of a composite shifter hollow cam-shafts for a sequential transmission includes portions formed of a wear resistant material and portions formed of a light weight material using laser surface quenching and discussed the static joining strength and fatigue strength of camshafts with different space between tooth. The destroying torsion of the shifter composite cam structure was (20-30) times as many as its actual work torsion, and its fatigue strength to allow the heavier, wear resistant material durable shifter cam, [5,6]. It can be studied a composite fabricated cam of Al-Sic using cold isostatic compaction and subsequent sintering die casting with a mixture of four different compositions (10, **??**0, **??**5, **??**0)% of Sic powder mixed with Al powders to obtain a high strength to weight ratio and low coefficient of thermal expansion and measured a cam properties like compressive strength, hardness, density and surface roughness, [7]. The fatigue life and microscopic edge cracks is measured for two open-celled foamed polymers having different densities in compression impact using a cam-driven compound pendulum system and observed that the material measurements at constant incident energy included the static compression modulus and peak dynamic stress, which progressively degraded as the number of impacts approached one million, [8].

3 II. BOX CAM SHAPE

1. Plate cam or disk cam:

The follower moves in a plane perpendicular to the axis of rotation of the camshaft. A translating or a swing arm follower must be constrained to maintain contact with the cam profile.

4 III. ANALYTICAL PROCEDURE

The general circular plate equation as a function of (r, and?) coordinates is:? ? 2 ?r 2 + 2 r ? ?r ? * M r + ?? 1 r ? ?r + 1 r 2 ? 2 ?? 2 ? * M ? + ?? 2 r ? 2 ?r ?? ? 2 r 2 ? ?? ? * M r? + q = 0**(1)**

Where:

For orthotropic plate, the bending and twist moments are: The value of first term of eq. (1) is:M r = ?[D r * ? 2 w ?r 2 + D 1 * (1 r ?w ?r + 1 r 2 ? 2 w ?? 2)] M ? = ?[D ? ? 1 r ?w ?r + 1 r 2 ? 2 w ?? 2 ? + D 1 * ? 2 w ?r 2]**(2)**M r? = 2 * ?? ? 2 ?r 2 + 2 r ? ?r ? * M r = ?(D r * ? 4 w ?r 4 + D 1 r ? 3 w ?r 3 + D 1 r 2 ? 4 w ?r 2 ?? 2 ? 2 * D 1 r 3 ? 3 w ?r ?? 2 + 2 * D 1 r 4 ? 2 w ?? 2 + 2 * D r r ? 3 w ?r 3

)

And the value of second term of eq. (1) is:?? 1 r ? ?r + 1 r 2 ? 2 ?? 2 ? * M ? = ?(? D ? r 2 ? 2 w ?r 2 + D ? r 3 ?w ?r + 2 * D ? r 4 ? 2 w ?? 2 ? D 1 r ? 3 w ?r 3 + D ? r 4 ? 4 w ?? 4 + D 1 r 2 ? 4 w ?r 2 ?? 2)

Also the value of third term of eq. (1) is:?? 2 r ? 2 ?r ?? ? 2 r 2 ? ?? ? * M r? = 2 * D r? (? 2 r 2 ? 4 w ?r 2 ?? 2 + 2 r 3 ? 3 w ?r ?? 2 ? 2 r 4 ? 2 w ?? 2)

It can be put the three terms derived above in eq. (1) to obtain:

The homogenous solution of eq. (1) is as follows:w(r, ?) H = A * sin(r * ?) + B * cos(r * ?)**(4)**

Where:

A and B are constants.

It can be derived the homogenous solution (1, 2, 3, 4) times with respect to r and ? to obtain: And the particular solution is:w(r, ?) P = C * r * ?**(6)**

Put eq. (6) in plate equation eq. (1) and find the value of constant (C):C = q * r 3 ? * D ? w(r, ?) P = q * r 4 D ?**(7)**

The complementary solution of deflection is as below:

w?r, ?? = w(r, ?) H + w(r, ?) P w?r, ?? =

It can be applied the boundary conditions on eq. (8) to obtain the constants (A and B): Where: Atr = r 1 = 2.C 1 = 2 * D r * ? 1 3 * r 1 2 +6 * D 1 * r 1 2 * ? 1 +12 * D r? * r 1 2 * ? 1 ?D ? * ? 1 D r * ? 1 4 * r 1 3 +D ? * ? 1 2 * r 1 +2 * D 1 * r 1 3 * ? 1 2 +4 * D r? * r 1 3 * ? 1 2 ?2 * D 1 *C 1 * C 2 * (tan(r 1 * ? 2) * cos(r 1 * ? 1)?sin(r 1 * ? 1)) ? * sin(r * ?) + q * r 4 D ?**(9)**

It can be assumed that the two points of contact load are as the simply-supported beam subjected to distributed load (P o) per unit length of point loading using superposition theory as illustrated in Fig. **??**3), [9]:P o = 0.6 * ? y q = P o * 2 * ? 3 * L 2 8 * 1 L 1 * ? F (**10**)

Where:

L: is the length of simply-supported beam.

L 1 :is the difference length between two points of contact.

? F : is the fiber volume fraction (? F = 0.3)

The elliptic equation is, [10]: w(x, y) = q * (

Where: a 1 and b 1 is the major and minor distance axis of ellipse.

And; H = D 1 + 2 * D r? And the semi-circle equation is, [10]:VII (A) w(r, ?) = ? [4 * q * r 4 ? * m 1 * ?16?m 1 2 ? * ?4?m 1 2 ? * D r + A 1m 1 * r m 1 + A 3m 1 * r m 1 +2] ? m 1 =1,3,5 * sin (m 1 * ?) (**12**)

Where: 2) : Cam Profile Specifications, [11]. IV.A 1m 1 = ?2 * q * (m 1 +1) * a 2 4?m 1 ? * m 1 * ?16?m 1 2 ? * ?4?m 1 2 ? * D r A 3m 1 = 2 * q * (m 1 ?1) * a 2 2?m 1 ? * m 1 * ?16?m 1 2 ? * ?4?m 1 2 ? * D r

5 NUMERICAL PROCEDURE

For this problem, the (SHELL 99)element is used in this paper for the two-dimensional modeling of orthotropic un-symmetric cam shell structure carried out with ANSYS 12.1 program software and is defined byeight nodes having six degrees of freedom at each node: translations in the nodal x, y, and z directions and rotations about the nodal x, y , and z axes to find the maximum deflection on cam boundaries. The mesh generation of box cam can be indicated in Fig. (4). Table (3) shows the theoretical and ANSYS results for deflection vary with point's number of nose no. 2 and flank no. 3. The deflection of cam boundary profile decreased transiently with the increasing of point's number on orthotropic cam boundaries because varying the radius of curvature at these points from the point of beginning at nose no. 2 to the point of ending at flank no. 3.

6 VI. CONCLUSIONS

1) The deflection of orthotropic cam is larger than the deflection in isotropic cam because the modulus of elasticity and Poisson's ratio for orthotropic cam is small for the same contact loading.

2) The maximum deflection occurs at nose no. (2) because the radius of curvature is small. 3) The deflection on noses is larger thanthe deflection of flanks because the effect of the radius of curvatures. [1] [2] [3] [4]

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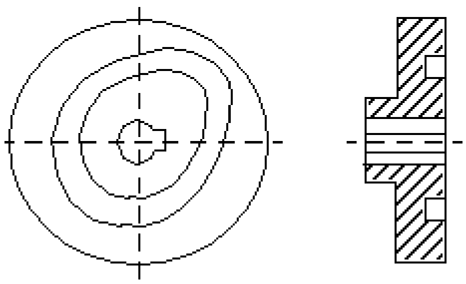
Figure 1: 1 1



2

Figure 2: 2 .

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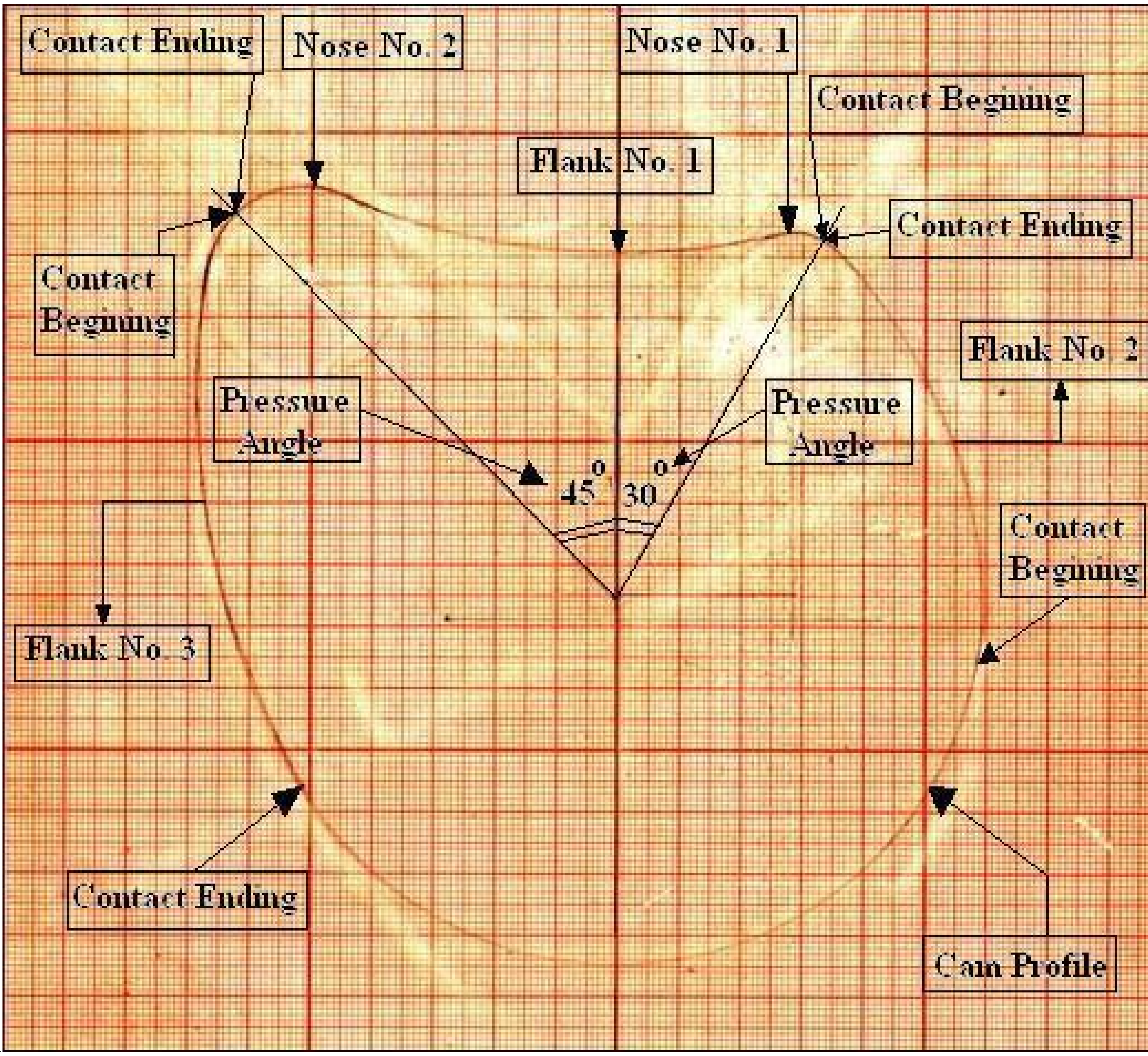
[3] Predictive Model of Orthotropic Un-Symmetric Box Cam Based On Deflection And countered by Segments of Circular-Arc Contact Profiles © 2011 Global Journals Inc. (US)

[4] Predictive Model of Orthotropic Un-Symmetric Box Cam Based On Deflection And countered by



1

Figure 3: Fig. (1

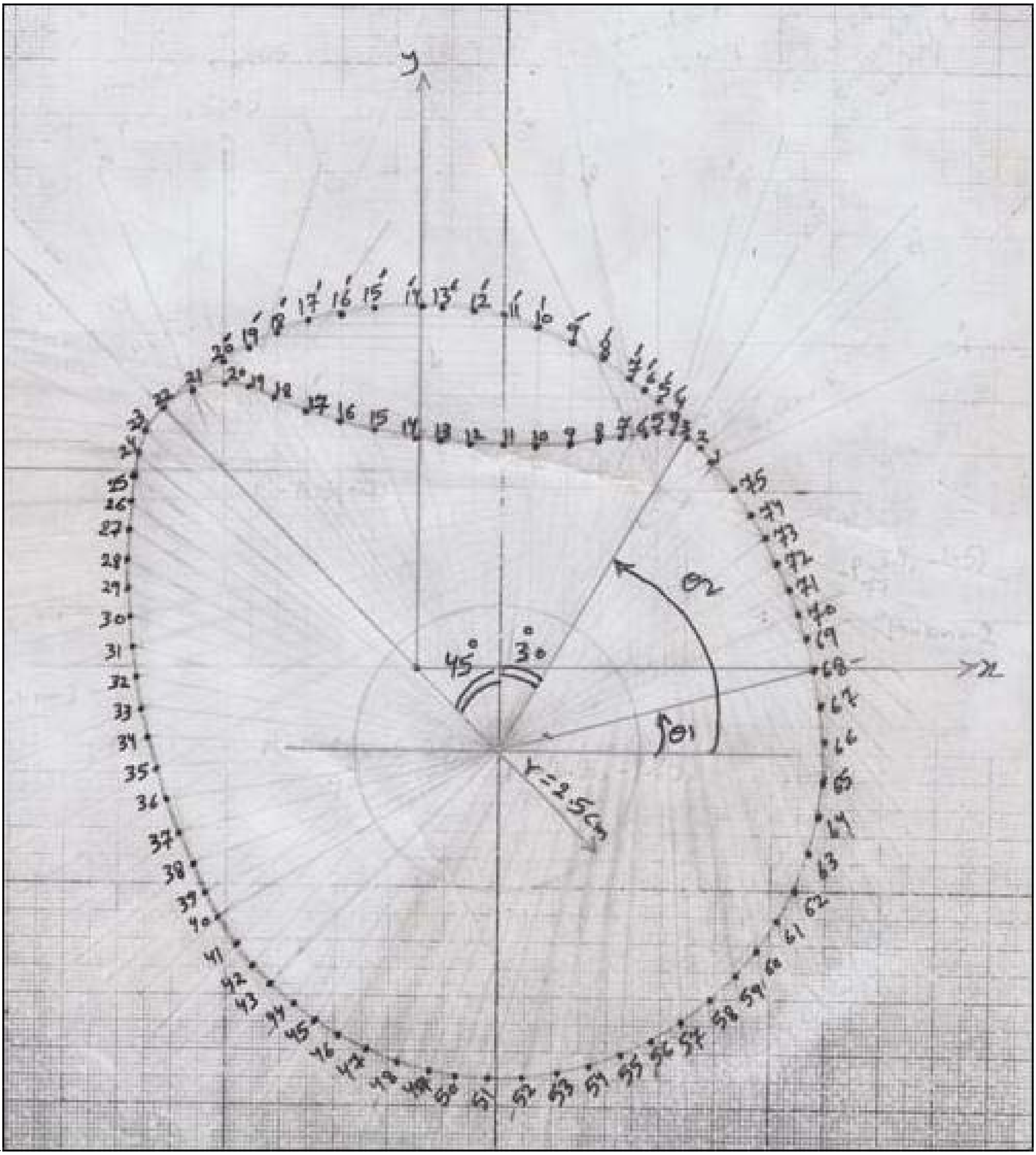


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Figure 4: A 1 =

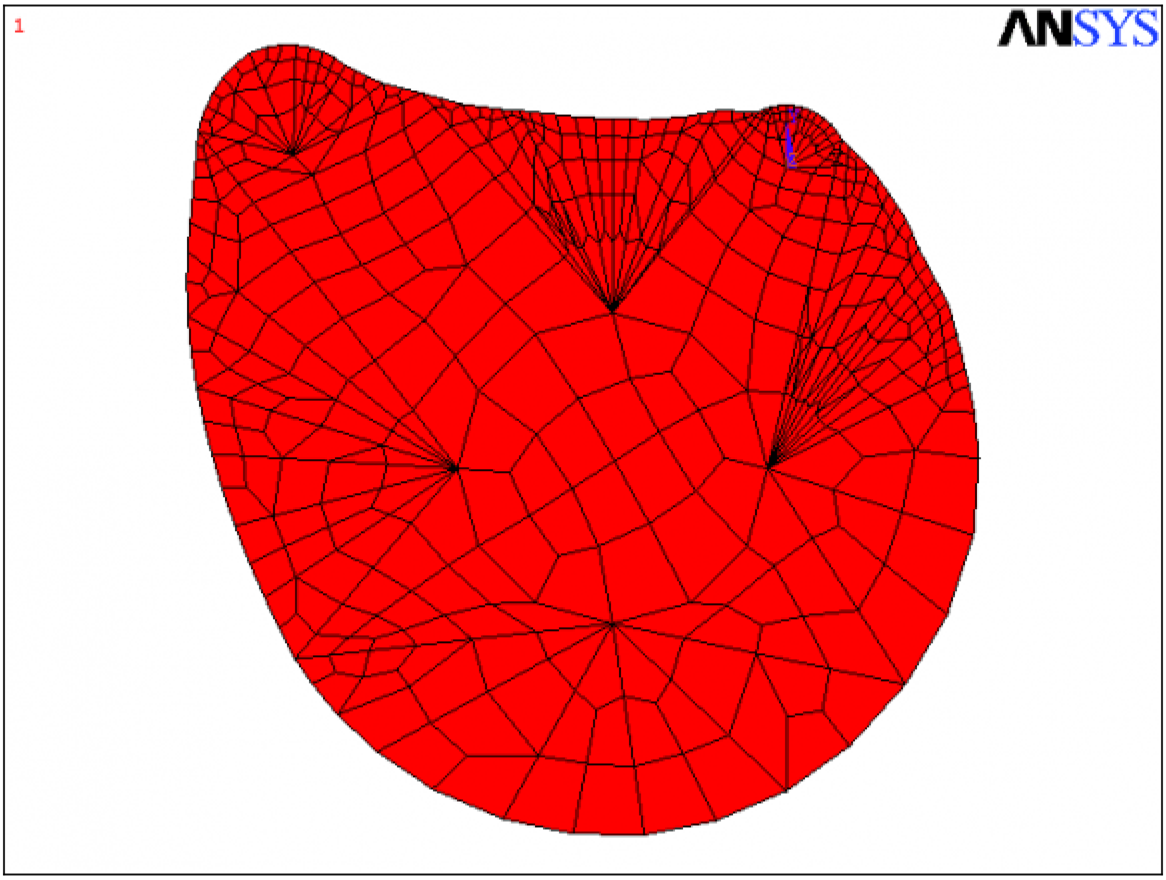
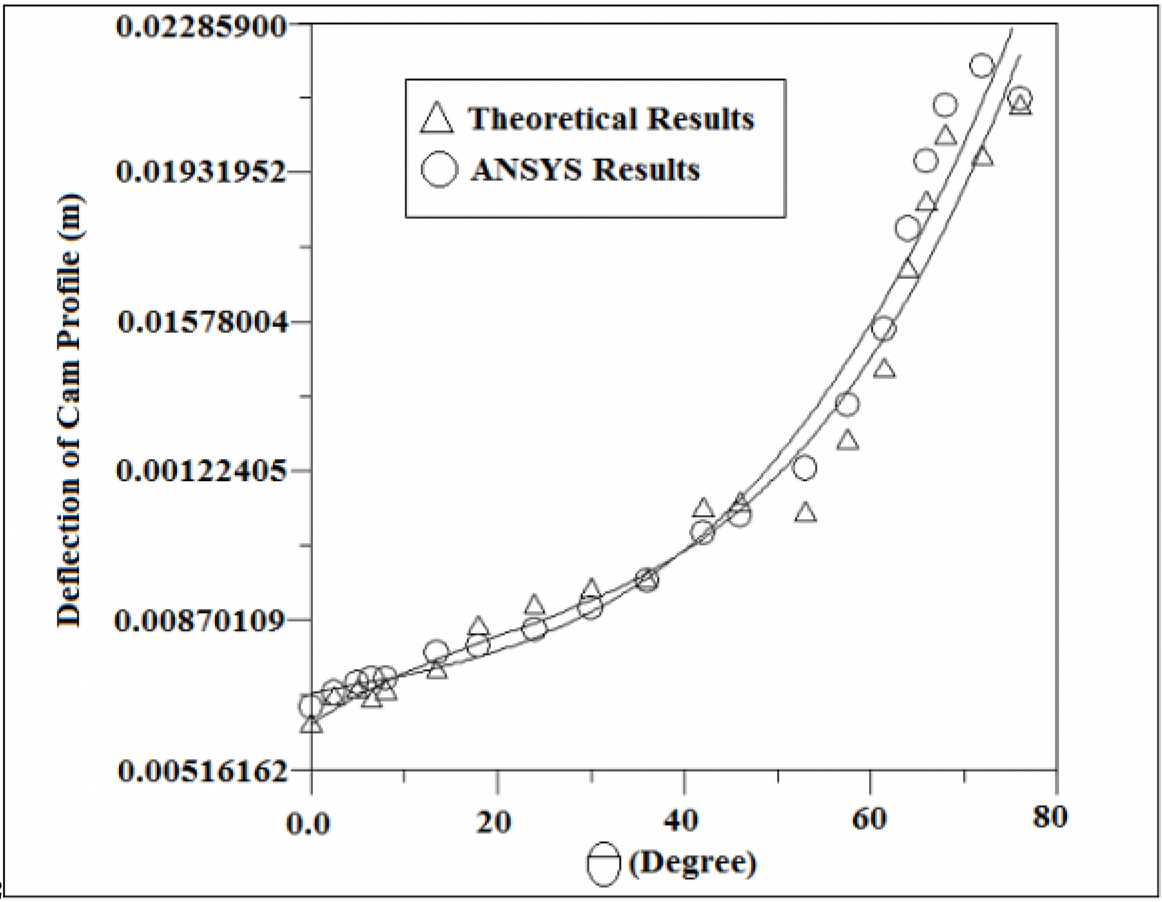


Figure 5:

2



0.02285900
0.01931952
0.01578004
0.00122405
0.00870109
0.00516162
Deflection of Cam Profile (m)
Theoretical Results
ANSYS Results
0.0
20
40
60
80
(Degree)

Figure 6: (2 *

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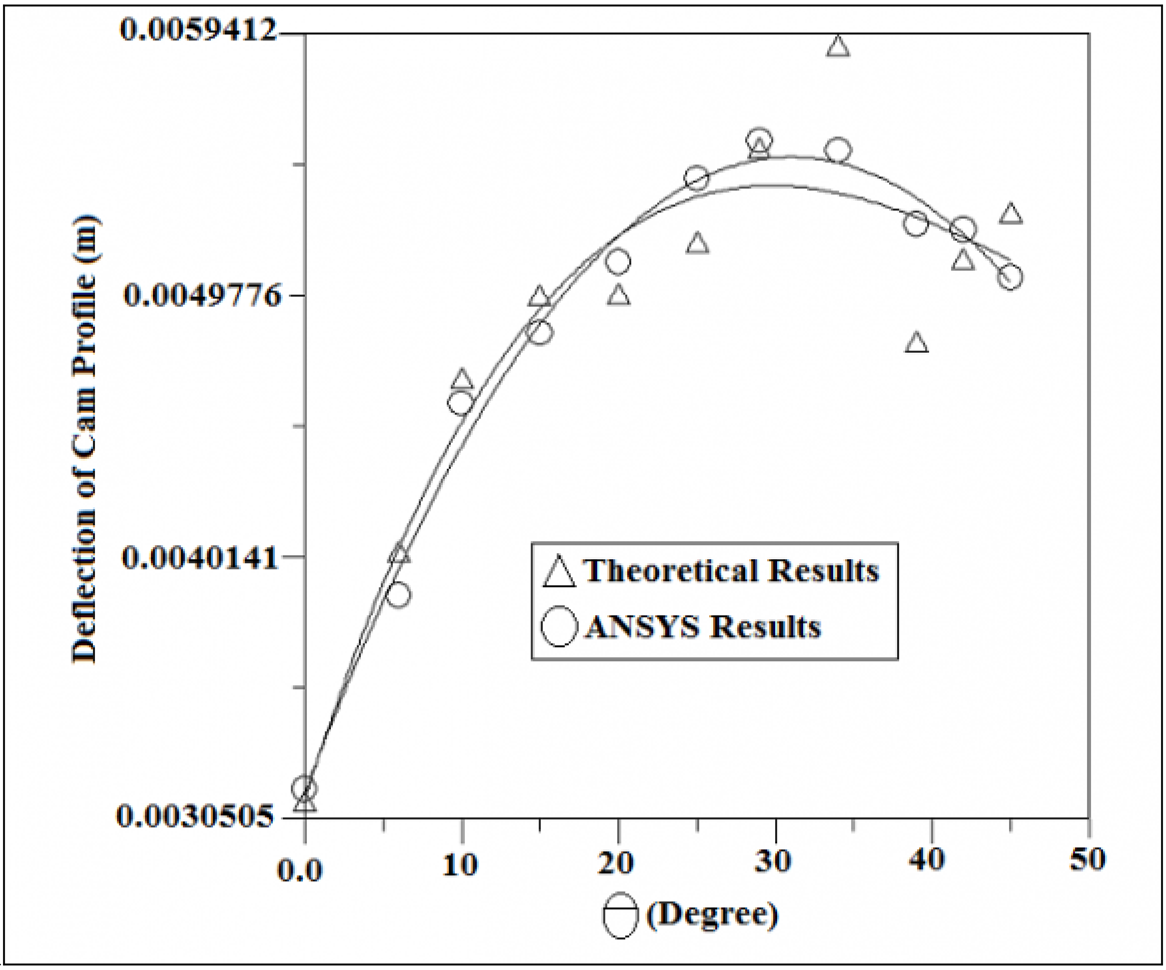

Figure 7: 2 Predictive 3 C 1 *

2

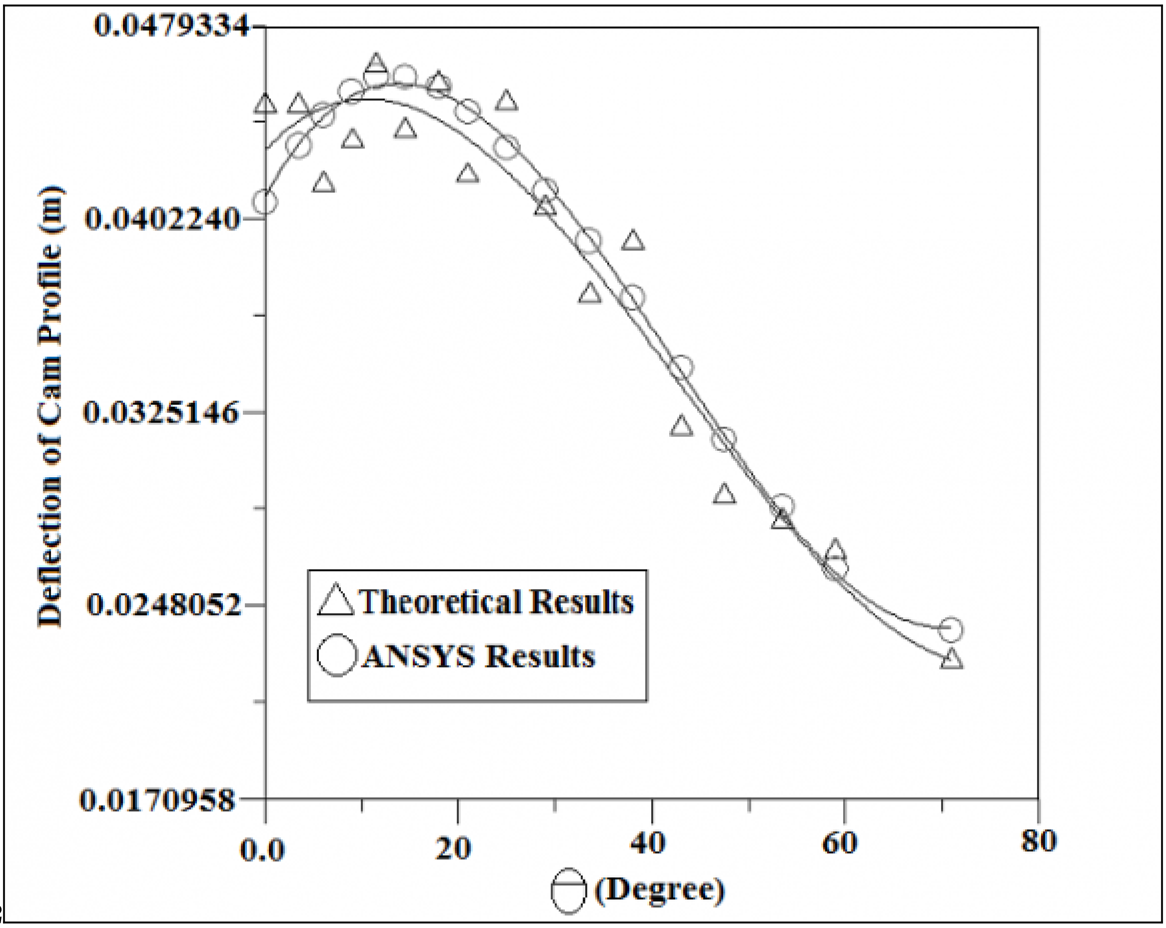

Figure 8: 2 ?

Figure 9:

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Points Number	Theoretical Results	ANSYS Results	Error (%)
3	0.005161615	0.0056644	8.876%
4	0.0058861	0.006051	2.725%
5	0.00606744	0.0063089	3.827%
6	0.00582013	0.0064287	9.466%
7	0.0060445	0.006436	6.083%
8	0.00661729	0.0071268	7.149%
9	0.00778991	0.0073008	6.278%
10	0.0083432	0.0077435	7.187%
11	0.00878378	0.0083321	5.142%
12	0.00903007	0.0090455	0.17%
13	0.0109305	0.010322	5.566%
14	0.0110767	0.010799	2.507%
15	0.0108222	0.012067	10.31%
16	0.0127715	0.01377	7.251%
17	0.01467905	0.015786	7.012%
18	0.0173589	0.018493	6.132%
19	0.01916212	0.020308	5.642%
20	0.0209437	0.021801	3.932%
21	0.0203995	0.022859	10.76%
22	0.0217526	0.021979	1.03%

Figure 10: Table (1

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Figure 11: Table (1

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Points Number	Theoretical Results	ANSYS Results	Error (%)
68	0.0030505	0.0031101	1.916%
69	0.004008805	0.0038517	3.918%
70	0.00466814	0.0045842	1.798%
71	0.004986	0.0048537	2.653%
72	0.0049904	0.0051238	2.603%
73	0.00519162	0.0054449	4.651%
74	0.0055525	0.0055893	0.658%
75	0.00594125	0.005553	6.691%
1	0.00480574	0.0052705	8.818%
2	0.005125194	0.0052481	2.342%
3	0.005301403	0.0050653	4.453%

Figure 12: Table (2

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Figure 13: Table (2

(

Points Number	Theoretical Results	ANSYS Results	Error (%)
22	0.0458897	0.040823	11.041%
23	0.0458858	0.043772	4.606%
24	0.0418067	0.045346	7.805%
25	0.0440422	0.046558	5.403%
26	0.0479334	0.047361	1.194%
27	0.04459053	0.047317	5.762%
28	0.0470031	0.046831	0.3661%
29	0.04224056	0.045533	7.231%
30	0.0460082	0.043685	5.049%
31	0.0405565	0.041455	2.167%
32	0.0360775	0.038849	7.134%
33	0.0387652	0.035871	7.466%
34	0.029147	0.032265	9.663%
35	0.0256657	0.028528	10.033%
36	0.02435666	0.025104	2.977%
37	0.02280797	0.021889	4.029%
39	0.0170958	0.018668	8.421%

Figure 14: Table (3

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