Determination of Stresses on the Carbide Insert While Grooving By Using Ansys

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Abstract— This paper presents, the determination of stresses acting on a carbide insert while performing a grooving operation will investigate experimentally. In grooving operation, different types of stresses are developed and due to those stresses, various wear are produced on insert tips such as crater wear, flank wear, thermal wear and mechanical wear. So that to overcome the effect of wear, we are performing the grooving operation at different working conditions to increase the efficiency, surface finishing and life of the insert. Stresses developed on insert tip are analyzed theoretically by orthogonal formulation and experimentally by using finite element analysis software ANSYS. Actual values of stresses acting on tip of the insert and calculated theoretical values of stresses then compared at different parameters.

Keywords: Grooving, CVD, Wear, Forces, Analysis

I. Introduction

Grooving is a multistep machining operation. It is a process of forming a narrow cavity of a certain depth, on a cylinder, cone, or face of a part. The groove will be in the shape of the cutting tool. For single-cut grooving generally, straight cuts can be made for groove widths of up to 8 mm giving the best method, chip control, and tool-life. The most common methods of rough machining wide grooves, or turning between shoulders, are multiple grooving, plunge turning, and ramping [2].

Recommended ring width is 0.6 to 0.8 times the insert width. This is a flexible method that is quick to program and geometry GM is the first choice for this method. To achieve the best roughing results in the form of a flat groove-bottom with the best groove-side quality. To achieve the best finishing results, care should be taken when machining the corners of the groove Then optimize the process in relation to the batch sizes. The Wiper effect generates a good surface finish with Ra values down to 0.2 microns [2].

II. Grooving

Machining grooves have many similarities to parting off, especially deep grooves. Although the same tool holder systems can be used for both parting and grooving in many instances, the insert geometries are dedicated to providing optimum performance and results. There are shallow grooves, deep grooves, wide grooves, external grooves, internal grooves, and face grooves. The insert corner is protected and chips are directed into the middle of the chip breaker [2].

Fig. 1: Grooving

A. Types of Grooving

1) Circlip grooving: The need of circlips on shaft and axle components is very common and there are two systems suitable for these grooving operations, and also have specific widths for circlip grooves.
2) Face grooving: A face grooving operation is carried out for remove the material from the face of workpiece.
3) Internal grooving:- Most of the methods for external grooving can be applied to internal grooving. Precautions may have to be considered, to ensure chip evacuation and to minimize vibration tendencies.

B. Inserts

An insert is a tool which uses for the grooving operation, the insert will work at a relatively high cutting speed and must be able to resist deformation. Therefore, needs more tough tool material for this operation. Advanced insert geometries are necessary for performing parting and grooving operations in a satisfactory way [2].

For this project, the selected material for deep grooving operation is carbide which is CVD coated type carbide insert. Coating of TiCN and TiN is done on carbide insert and improved toughness and stability due to specialized carbide substrate with plastic deformation resistance [6].

SN	Quantity	Value	Unit
1	young's Modulus	530000-700000	MPa
2	Transverse strength	2.7	GPa
3	Fatigue	270-300	MPa
4	Hardness	13.7	Gpa
5	Ratio	0.31	-

Table 1: Mechanical Properties

A positive-rake insert gives lower cutting forces and thus lower pressure on the workpiece and this will reduce the size of the tip. On neutral or straight inserts the lead angle is zero. A reduced lead angle produces larger radial cutting forces but this can cause vibration problems especially when small diameters are machined [5].

With grooving and parting operations, the insert has machined surfaces on both sides of the feed direction.

1) Types of Chip Breaker-

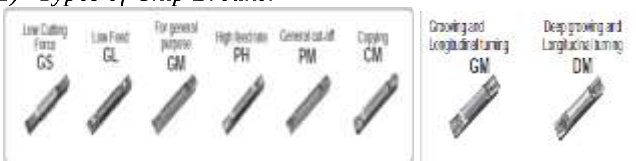

Fig. 2: Types of Chip Breaker

Effect of wear on chips-

Generally, there are three basic types of chips form due to wear out inserts

- Discontinuous chips
- Continuous chips with buildup edges
- Inhomogeneous Chip.

III. FAILURE OF INSERTS WHILE GROOVING AND RESEARCH METHODOLOGY

A. Failure:-

Failure carbide insert is a common phenomenon in Grooving operation. Mainly it happens due to improper insert working and cutting force. To achieve the better possible economies of tool life, workpiece quality, and optimized cutting data, careful observations of the insert edge have to be made. At low speeds, built-up edge (BUE) and chipping are the main problems; at high speeds, plastic deformation (PD), flank wear, and crater wear are the problems.

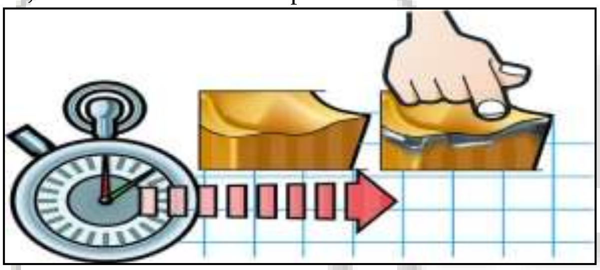

Fig. 3: Failure of insert [2]

IV. FORMULATION

A. Orthogonal Cutting

Orthogonal cutting is only an approximation of the actual scenario; the assumptions used in the orthogonal metal cutting analysis are noted below

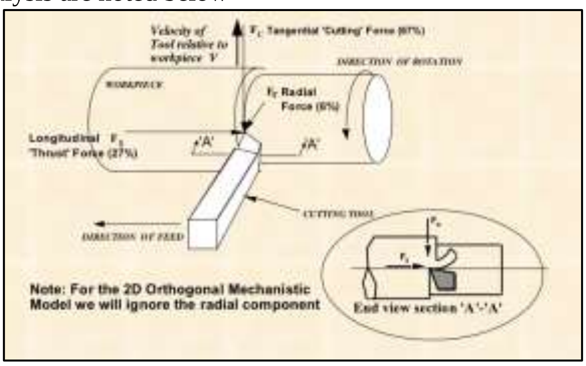

Fig. 4: Turning forces for orthogonal model

1) No contact at the flank i.e. the tool is perfectly sharp
2) No side flow of chips i.e. width of chips remains constant.
3) The cutting velocity remains uniform.
4) A continuous chip is produced with no build-up edge.
5) The work material undergoes deformation across a thin shear plane.
6) There is a uniform distribution of normal and shear on the shear plane.
7) The work material is rigid and perfectly plastic.

B. Working Conditions for Grooving Operation

- Power = 27 kw
- Rpm = 1) 1000
  2) 1400
  3) 1800
  4) 2200
- Depth of cut (d)= 0.2mm
- Feed rate (f)= 0.15mm/rev
- Cutting velocity (Vc)= 150m/min
- Coefficient of friction(μ) = 0.63

C. Calculations for 1000 RPM

Here

μ = Coefficient of friction

μ=0.63, we know that

μ = tan β

1) Friction Angle

β = Friction Angle

0.63 = tan β β = $\tan^{-1} 0.63$

β = 32.21° ….1

2) Rake angle

α= rake angle α= 7 ° ….2

3) Shear angle

ϕ = Shear angle

$$\phi = 45 + \frac{\alpha}{2} - \frac{\beta}{2}$$

$$\phi = 32.395^\circ \quad \text{….3}$$

4) Chip thickness ratio

The chip thickness ratio is sometimes used as a measure of the quality of the surface finish, where r is high, the cutting action & quality of the surface are generally good.[5]

r= chip thickness ratio

$$r = \frac{\sin\phi}{\cos(\phi-\alpha)}$$

$$= \frac{\sin 32.395}{\cos(32.395-7)}$$

r = 0.5930 …. 4

D. Velocity Relationships

If Vc is cutting velocity, VF is the chip flow velocity and VS is the shear velocity, a vector triangle can be formed in the cutting zone to establish a relationship of VF and VS with Vc. In the vector triangle, the ratio of the vector to the sine of the opposite angle will be equal[5].

1) Cutting velocity

V_C = cutting velocity

Given range for grooving is in range from 100 m/min to 200 m/min

We preferred 150 m/min

V_C= 150 m/min ….5

2) Chip flow velocity

V_f=r. V_C

= 0.5930 (150)

= 88.95 m/min ….6

3) Shear velocity

$V_S = \frac{\cos 7}{\cos(32.395-7)} Vc$

= 164.80 m/min ….7

E. Working Conditions

Spindle power = 27×10 ^{3}W
Spindle speed = 1000 RPM
We know that

$$P = \frac{2\pi NT}{60} \qquad T = \frac{27000\times 60}{2\pi\times 1000}$$

T=257.83N-m ….8

Torque = Force × perpendicular distance

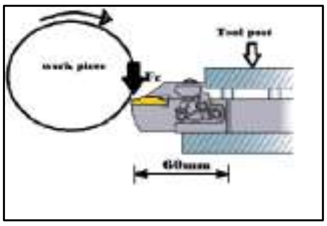

Fig. 5: Position of cutting force

Perpendicular distance from tool post = 0.06m
Force = 257.83 ÷ 0.06
= 4297.18 N

F. Forces in Metal Cutting

Metal cutting involves a large amount of force. The power supplied for cutting is utilized mainly in sharing the material and overcoming the frictional forces between the tool and the chip. It is important to ascertain the cutting forces acting during metal cutting, for calculation of power required in metal cutting to properly design cutting tools, for a proper design of jigs and fixtures used to hold the workpiece during the cutting operation, and for selection of suitable operating conditions like speed, feed, and depth of cut.

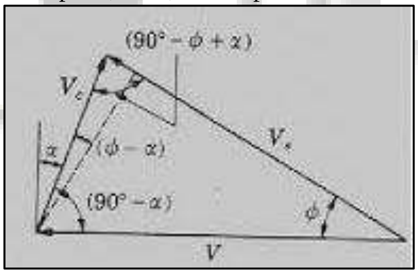

Fig. velocity triangle

Cutting force

F_C= 4297.18 N ….9

Fc = R ·cos (β-α)

4297.18 = R .cos (32.21-7)

Resultant force

R = 4749.56 N ….10

Tangential force

Ft = R ·sin (β-α) = 4749.56 sin (32.21-7)

Ft =2023.01N 11

Fiction force

F = R·sin (β) = 4749.56sin (32.21)

= 2531.62 N ….12

Normal to Fiction force

N = R·cos(β) = 4742.56cos (32.21)

=4018.60 N ….13

Shear force

Fs= Fc ·cos(φ) − Ft ·sin(φ)

=4297.18cos (**32.395**) –2023.01sin (**32.395**)

= 2544.60N ….14

Normal to shear force

Fn= Fc ·sin (φ) + Ft ·cos(φ)

=4297.18 sin (**32.395**) + 2023.01cos(**32.395**)

= 4010.60N ….15

Stress calculations

Here,
Width of cut (w)=5mm
Uncut chip thickness (t_0) = 0.2mm

Cross sectional area of the chip before removal (A_o) = 1mm^2

Area of shear plane(A_s)

$$As = \frac{Ao}{\sin\phi} = \frac{1}{\sin 32.395} = 1.8665$$

Shear stress $\tau = \frac{Fs}{As}$

From the above formula values of stresses at different RPM are as below

SN.	N (RPM)	Forces (N)	ϛ(shear stress) Mpa
1	1000	4378.18	1363.29
2	1400	3069.41	973.78
3	1800	2387.32	757.24
4	2200	1953.16	619.94

V. MODELLING AND ANALYSIS

A. Modelling

After determining the type of analysis required and the characteristics of the operating environment, the engineer must produce a finite element model with appropriate analysis parameters, such as loads, constraints, and a suitable mesh.

Modeling of grooving insert is carried out in CAD software Creo Parametric 2.0. We drafted the design in the sketcher module with the available dimensions of the blade. Modeling was finalized in part design workbench.

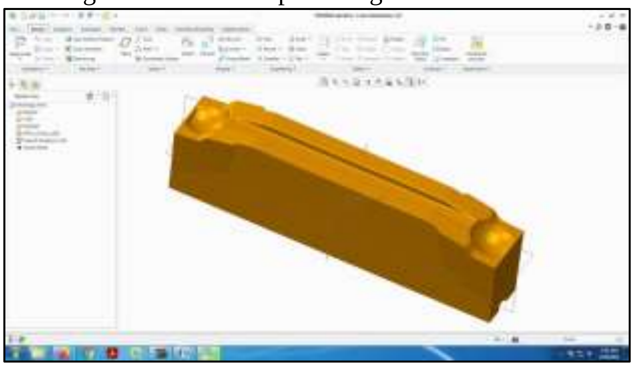

Fig. 6: grooving insert in part modeling in Creo Parametric

B. Analysis

1) Introduction to ANSYS software

ANSYS is a general-purpose finite-element modeling package for numerically solving a wide variety of mechanical problems. These problems include static dynamics, structural analysis (both linear and nonlinear), heat transfer, and fluid problems, as well as acoustic and electromagnetic problems. In general, a finite-element solution may be broken into the following three stages.

a) Pre-processing: defining the problem
The major steps in pre-processing are

1) Define key points/lines/areas/volumes,
2) Define element type and material/geometric properties, and
3) Mesh lines/areas/ volumes as required.

The amount of detail required will depend on the dimensionality of the analysis, i.e., 1D, 2D, Axisymmetric, and 3D.

Solution: assigning loads, constraints, and solving
Here, it is necessary to specify the loads (point or pressure), constraints (translational and Rotational), and finally solve the resulting set of equations.

C. Post-processing: further processing and viewing of the results

In this stage, one may wish to see

1) Lists of nodal displacements,
2) Element forces and moments,
3) Deflection plots, and
4) Stress contour diagrams or temperature maps

Modeling and analysis of Grooving insert are presented. For Modeling of Grooving insert we used CAD software Creo Parametric 2.0. We drafted the design in the sketcher module with the available dimensions of the insert. Modeling was finalized in part design workbench. For analysis, we used analysis software ANSYS 19 R3. After preparing a solid Geometry model the important steps are meshing and applying loading and boundary conditions

VI. RESULTS AND DISCUSSION

The analytical results of the maximum cutting force acting on the insert (Fc), torque (T), were obtained also we obtained the force and torque on the grooving insert for three different RPM and Coefficient of friction. All these results are presented in this.

A. Analytical results

We have calculated cutting forces by an analytical method and they are 4297.18N,3069.41N,2387.32N,1953.16N at 1000 RPM, 1400 RPM, 1800 RPM, and 2200 RPM. On the other side, stresses that develop at insert are as follows.

Sr. No	RPM	Stress (MPa)
1	1000	1363
2	1400	973.78
3	1400	757.24
4	2200	644.78

Table 1: Theoretical stresses at different RPM

B. Software results

Modeling and analysis of grooving insert were carried out in CATIA and ANSYS software respectively. We obtained results for different RPM. For that, we use the force acting on the holder calculated in section and for three RPM. Results are shown below

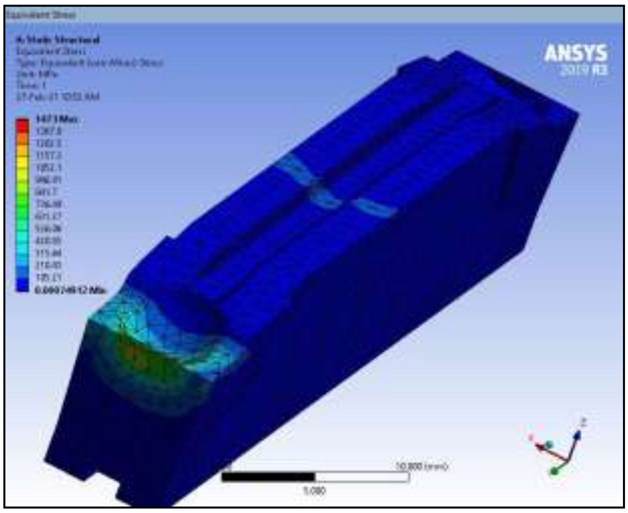

Fig. 7: Von misses stress on grooving insert in ANSYS

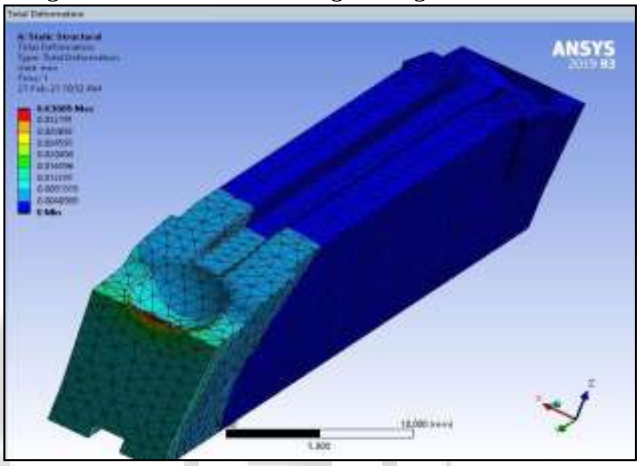

Fig. 8: Grooving insert nodal displacements in ANSYS

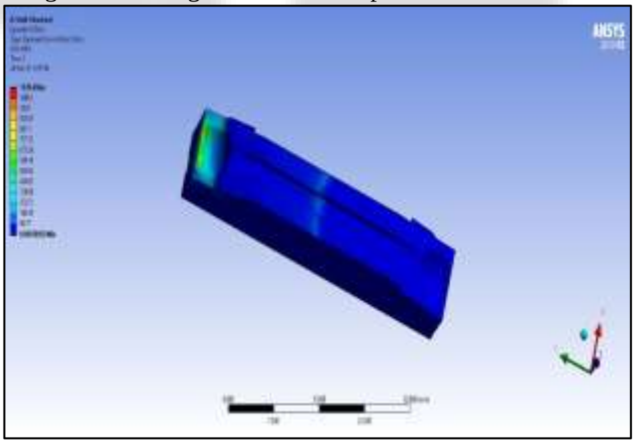
Fig. 9: Von misses stress on grooving insert in ANSYS

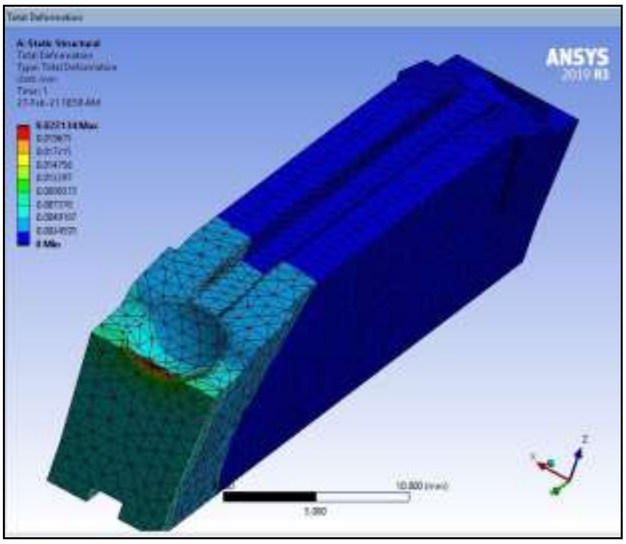

Fig. 10: Grooving insert nodal displacements in ANSYS

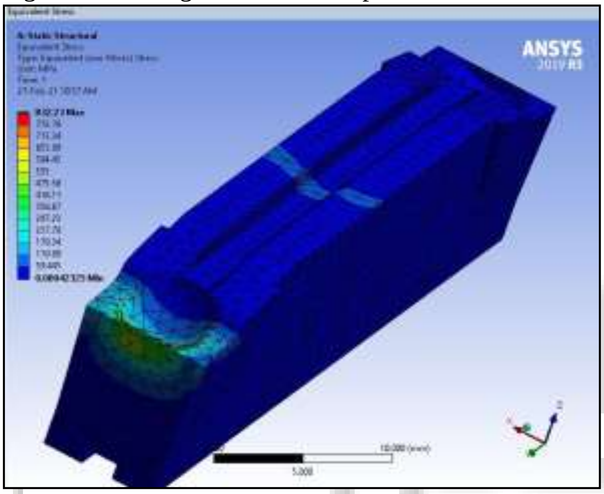

Fig. 11: Von misses stress on grooving insert in ANSYS

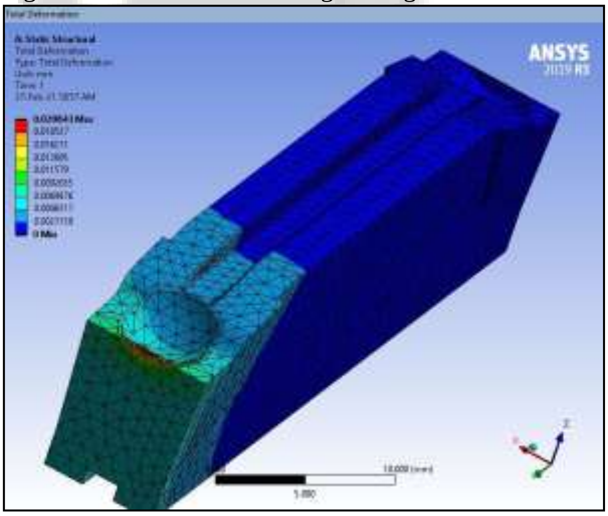

Fig. 12: Grooving insert nodal displacements in ANSYS

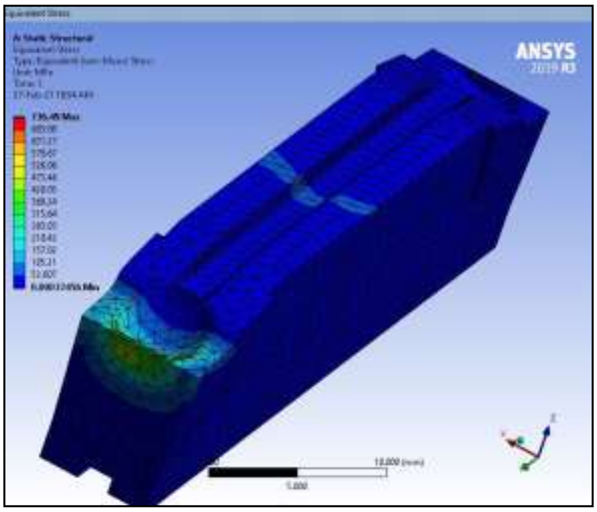

Fig. 13: Von misses stress on grooving insert in ANSYS

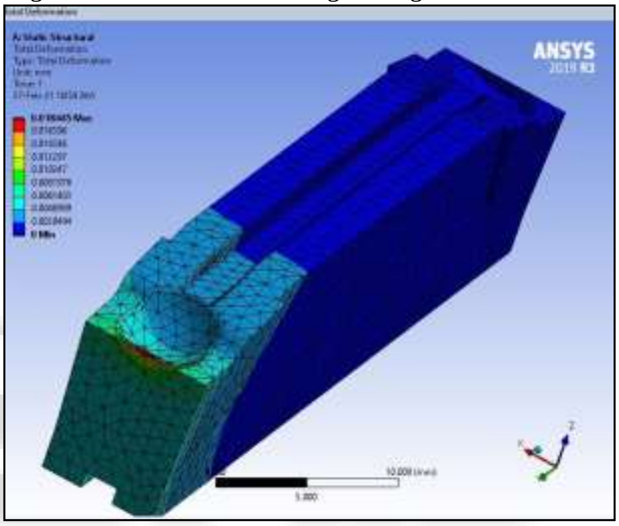

Fig. 14: Grooving insert nodal displacements in ANSYS

Sr. No	RPM	Von mises Stress (M Pa)
1	1000	1473
2	1400	1178.4
3	1400	832.32
4	2200	736.49

Table 2: Von misses stresses at different RPM

Results obtained from the calculations and the software are presented. The Analytical results of the maximum cutting force acting on the Grooving insert (Fc), torque (T), Von misses stress was presented in the software results (with diagrams) were presented in which includes vector displacement diagram and Von mises stress for three different RPM and Torques.

Sr. No	Theoretical stresses (Mpa)	Von mises Stress (MPa)
1	1363	1473
2	973.78	1178.4
3	757.24	832.32
4	644.78	736.49

Table 3: stresses Comparison

VII. Conclusion

Here, by the overall study of grooving Insert and its failure pattern, we conclude the following points

1) CAD method has been explored for the design and analysis of Grooving Insert and Finite Element Analysis was done for investigation of stresses experienced by the Insert. A comparison was made between the stresses acting on the tip of the insert for different RPM of the CNC spindle.
2) The comparative study showed that stresses are minimum for the insert when grooving at 2200 RPM compared to Grooving at 1000 RPM. This ultimately shows the Grooving Inserts life is dependent upon torque and RPM.
3) Calculation of shear stress and von misses stress showed that at all the four values of N (RPM), values of yield strength are less than calculated values. So Insert is going to fail at this working condition.

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