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Design and Buckling Analysis of Two Wheeler Connecting Rod Using Different Materials

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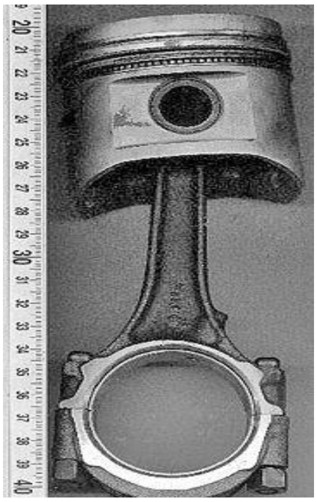
Abstract:
Connecting rod is the mediator between the piston and the crank. And its function is to transmit the thrust from the piston pin to crank pin, thus converting the reciprocating motion of the piston to rotary motion of the crank. Generally connecting rods are manufactured using carbon steel and in recent days aluminum alloys are used for manufacture the connecting rods. In this work existing connecting rod material is replaced by beryllium alloy and magnesium alloy. And this also described the modeling and analysis of connecting rod. FEA analysis was carried out by considering three materials Al360, beryllium alloy and magnesium alloy. In this study a solid 3D model of Connecting rod was developed using CATIA software and an analysis was carried out by using ANSYS 14.0 Software and useful factors like von mises stress, von mises strain and displacement were obtained.

INTRODUCTION:
Every Internal Combustion (I.C.) engine consists of mainly cylinder, piston, connecting rod, crank and crank shaft. The Connecting Rod is one of the important parts of an engine. Its work is to transmit the thrust of piston from piston pin generated by the burnt gas's pressure to the other part of engine called Crank via crank pin. It has two ends one is called small or piston end and other one is big or crank end. The big end make a joint with crank or crank shaft by crank pin and small end make a joint with piston by piston pin. It gives the rotating motion to the crank shaft by converting the reciprocating motion of piston into rotating motion. The connecting rod should be such that which can be withstand the maximum load without any failure during high cycle fatigue in operation. The fracture toughness also should be such that it does not go below a certain minimum limit. A further need is that the connecting rod should not buckle during operation. These requirements are used to select an appropriate cross section and material for manufacture . The connecting rod generally has a long shank, a small end and a big end. According to the requirements, the cross-section of the shank may be rectangular, circular, tubular, I-section or H-section. It has been observe that circular section is used for low speed engines and I-section is used for high speed engines. In a long research span it has been noted that during reciprocating motion of the piston a wear of cylinder wall occurs, Which is caused by sideways force of piston acting on cylinder wall and results in an oval cross-section rather than being circular. Due to which piston rings lose their closeness to the cylinder wall and are failed to seal the cylinder.

Geometrically, it can be seen that longer connecting rods will reduce the amount of this sideways force, and therefore may increase the engine life . A connecting rod is one of the most mechanically stressed components in internal combustion engines. There are different types of stresses induced in connecting rod. One of which is axial stress induced by cylinder gas pressure (compressive only) and second one is bending stress caused by centrifugal action and third one is inertial force generated by reciprocation of piston. The connecting rod has a tremendous field of research. In addition to this, vehicle construction led the invention and implementation of quite new materials which are light and meet design requirements. And the optimization of connecting rod had already started as early year 1983 by Webster and his team.

There are many materials which can be used in connecting rod for optimization.In this study three materials Al360, Beryllium alloy 25 and Magnesium alloy have considered for analysis. Tukaram S. Sarkate et al , (2013) carried out an analysis to find out an optimum material for connecting rod. The results obtain by FEA for both Aluminum 7068 alloy and AISI 4340 alloy steel are satisfactory for all possible loading conditions. Kuldeep B. et al, (2013) described in the study that Weight can be reduced by changing the material of the current Al360 connecting rod to hybrid alfasic composite. Leela Krishna Vegi, Venu Gopal Vegi, (2013), demonstrated that the factor of safety (from Soderberg's), stiffness of forged steel is more than the existing carbon steel found and The weight of the forged steel material is less than the existing carbon steel and reported that by using fatigue analysis life time of the connecting rod can be determined.

B. Anusha et al (2013), clarified in the paper and concluded that the stress induced in the structural steel is less than the cast iron for the present investigation. Pushpendrakumar Sharma et al (2012), performed the static FEA of the connecting rod using the software and took the advantages of using crackableforged steel (C70) in place of current forging steel for reducing weight of connecting rod. And the software gives a view of stress distribution in the whole connecting rod which gives the information that which parts are to be hardened or given attention during manufacturing stage. Ram bansal et al, in the paper a dynamic analysis was performed on a connecting rod made of aluminium alloy using FEA. The analysis was performed under dynamic to determine the in service loading of the connecting rod and FEA was conducted to find the stress atcritical points.

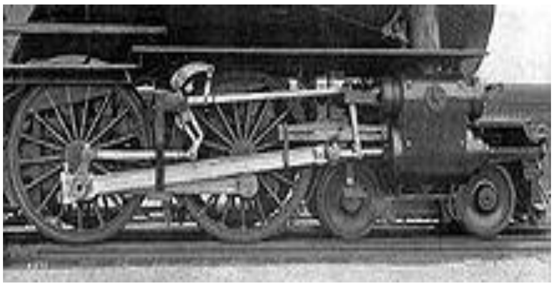


STEAM ENGINE

Beam engine, with twin connecting rods (almost vertical) between the horizontal beam and the flywheel cranks The first steam engines, Newcomen's atmospheric engine, was single-acting: its piston only did work in one direction and so these used a chain rather than a connecting rod. Their output rocked back and forth, rather than rotating continuously.

Crosshead of a stationary steam engine: piston rod to the left, connecting rod to the right

Steam engines after this are usually double-acting: their internal pressure works on each side of the piston in turn. This requires a seal around the piston rod and so the hinge between the piston and connecting rod is placed outside the cylinder, in a large sliding bearing block called a crosshead.



Steam locomotive rods, the large angled rod being the connecting rod. In a steam locomotive, the crank pins are usually mounted directly on one or more pairs of driving wheels, and the axle of these wheels serves as the crankshaft. The connecting rods (also called the main rods in US practice), run between the crank pins and crossheads, where they connect to the piston rods. Crossheads or trunk guides are also used on large diesel engines manufactured for marine service.

(The similar rods between driving wheels are called coupling rods in British practice.) The connecting rods of smaller steam locomotives are usually of rectangular cross-section but, on small locomotives, marine-type rods of circular cross-section have occasionally been used. Stephen Lewin, who built both locomotive and marine engines, was a frequent user of round rods.Gresley's A4 Pacifics, such as Mallard, had an alloy steel connecting rod in the form of an I-beam with a web that was only 0.375 in (9.53 mm) thick.

INTERNAL COMBUSTION ENGINE:

In modern automotive internal combustion engines, the connecting rods are most usually made of steel for production engines, but can be made of T6-2024 and T651-7075 aluminum alloys (for lightness and the ability to absorb high impact at the expense of durability) or titanium (for a combination of lightness with strength, at higher cost) for high-performance engines, or of cast iron for applications such as motor scooters. They are not rigidly fixed at either end, so that the angle between the connecting rod and the piston can change as the rod moves up and down and rotates around thecrankshaft. Connecting rods, especially in racing engines, may be called "billet" rods, if they are machined out of a solid billetof metal, rather than being cast or forged.

Small end and big end:

The small end attaches to the piston pin, gudgeon pin or wrist pin, which is currently most often press fit into the connecting rod but can swivel in the piston, a "floating wrist pin" design. The big end connects to the bearing journal on the crank throw, in most engines running on replaceable bearing shells accessible via the connecting rod bolts which hold the bearing "cap" onto the big end. Typically there is a pinhole bored through the bearing and the big end of the connecting rod so that pressurized lubricating motor oil squirts out onto the thrust side of the cylinder wall to lubricate the travel of the pistons andpiston rings. Most small two-stroke engines and some single cylinder four-stroke engines avoid the need for a pumped lubrication system by using a rolling-element bearing instead, however this requires the crankshaft to be pressed apart and then back together in order to replace a connecting rod.

Engine wear and rod length :

A major source of engine wear is the sideways force exerted on the piston through the connecting rod by the crankshaft, which typically wears the cylinder into anoval cross-section rather than circular, making it impossible for piston rings to correctly seal against the cylinder walls. Geometrically, it can be seen that longer connecting rods will reduce the amount of this sideways force, and therefore lead to longer engine life. However, for a given engine block, the sum of the length of the connecting rod plus the piston stroke is a fixed number, determined by the fixed distance between the crankshaft axis and the top of the cylinder block where thecylinder head fastens; thus, for a given cylinder block longer stroke, giving greater engine displacement and power, requires a shorter connecting rod (or a piston with smaller compression height), resulting in accelerated cylinder wear.

Stress and failure

Failure of a connecting rod is one of the most common causes of catastrophic engine failure. The connecting rod is under tremendous stress from the reciprocating load represented by the piston, actually stretching and being compressed with every rotation, and the load increases as the square of the engine speed increase. Failure of a connecting rod, usually called throwing a rod, is one of the most common causes of catastrophic engine failure in cars, frequently putting the broken rod through the side of the crankcase and thereby rendering the engine irreparable; it can result from fatigue near a physical defect in the rod, lubrication failure in a bearing due to faulty maintenance, or from failure of the rod bolts from a defect, improper tightening or over-revving of the engine. Re-use of rod bolts is a common practice as long as the bolts meet manufacturer specifications. Despite their frequent occurrence on televised competitive automobile events, such failures are quite rare on production cars during normal daily driving. This is because production auto parts have a much larger factor of safety, and often more systematic quality control.

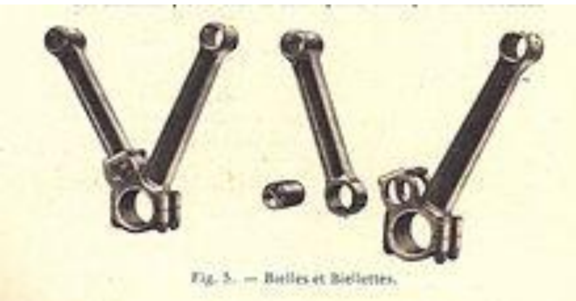
High-performance engines:

When building a high-performance engine, great attention is paid to the connecting rods, eliminating stress risers by such techniques as grinding the edges of the rod to a smooth radius, shot peening to induce compressive surface stresses (to prevent crack initiation), balancing all connecting rod/piston assemblies to the same weight and Magnafluxing to reveal otherwise invisible small cracks which would cause the rod to fail under stress. In addition, great care is taken to torque the connecting rod bolts to the exact value specified; often these bolts must be replaced rather than reused. The big end of the rod is fabricated as a unit and cut or cracked in two to establish precision fit around the big end bearing shell. Therefore, the big end "caps" are not interchangeable between connecting rods, and when rebuilding an engine, care must be taken to ensure that the caps of the different connecting rods are not mixed up. Both the connecting rod and its bearing cap are usually embossed with the corresponding position number in the engine block.

Powder metallurgy :

Recent engines such as the Ford 4.6 litre engine and the Chrysler 2.0 litre engine, have connecting rods made using powder metallurgy, which allows more precise control of size and weight with less machining and less excess mass to be machined off for balancing. The cap is then separated from the rod by a fracturing process, which results in an uneven mating surface due to the grain of the powdered metal. This ensures that upon reassembly, the cap will be perfectly positioned with respect to the rod, compared to the minor misalignments which can occur if the mating surfaces are both flat.

Compound rods

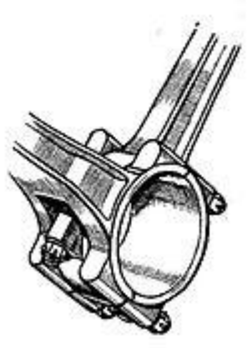


Articulated connecting rods

Many-cylinder multi-bank engines such as a V12 layout have little space available for many connecting rod journals on a limited length of crankshaft. This is a difficult compromise to solve and its consequence has often led to engines being regarded as failures (Sunbeam Arab, Rolls-Royce Vulture).In certain engine types, master/slave rods are used rather than the simple type shown in the picture above. The master rod carries one or more ring pins to which are bolted the much smaller big ends of slave rods on other cylinders. Certain designs of V engines use a master/slave rod for each pair of opposite cylinders. A drawback of this is that the stroke of the subsidiary rod is slightly shorter than the master, which increases vibration in a vee engine, catastrophically so for the Sunbeam Arab.

BMW 132 radial aero engine rods:

Radial engines typically have a master rod for one cylinder and multiple slave rods for all the other cylinders in the same bank.



Fork and blade rods:

The usual solution for high-performance aero-engines is a "forked" connecting rod. One rod is split in two at the big end and the other is thinned to fit into this fork. The journal is still shared between cylinders. The Rolls-Royce Merlin used this "fork-and-blade" style. A common arrangement for forked rods is for the fork rod to have a single wide bearing sleeve that spans the whole width of the rod, including the central gap. The blade rod then runs, not directly on the crankpin, but on the outside of this sleeve. The two rods do not rotate relative to each other, merely oscillate back and forth, so this bearing is relatively lightly loaded and runs as a much lower surface speed. However the bearing movement also becomes reciprocating rather than continuously rotating, which is a more difficult problem for lubrication.

PROBLEM FORMULATION:

The objective of the present study is to design and analysis of two wheeler connecting rod and to find the best alternative material of connecting rod. In the present study beryllium alloys and magnesium alloys have taken in place of currently using materials like aluminum 360 for CAE analysis and a meaningful comparison made among AL360, Beryllium alloy and Magnesium alloy for choosing the alternative of existing material using for manufacture the connecting rod of single cylinder 4 stroke combustion engines.

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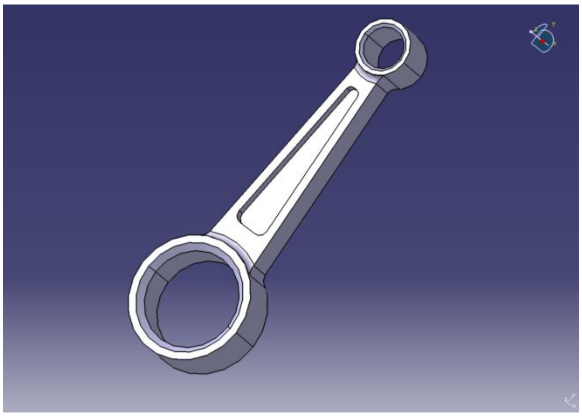
In this work, an analysis is done for aluminium alloy, magnesium alloy and beryllium alloy. Beryllium alloys feature high fatigue strength and resistance to wear, corrosion, galling, and stress relaxation.

DESIGN OF CONNECTING ROD

Sr No	Parameter	Value
1	Length of connecting rod	94.27mm
2	Outer Diameter of Big end	39.02mm
3	Inner Diameter of Big end	30.19mm
4	Outer Diameter of Small end	17.75mm
5	Inner Diameter of small end	13.02mm

Dimensions of connecting rod



Design in CATIA V5

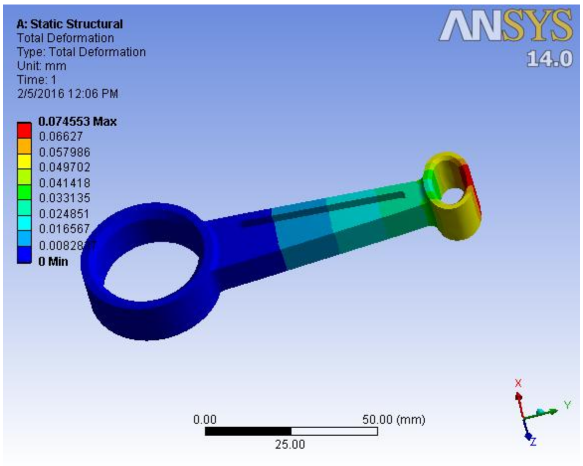
ANALYSIS

Table: Material Information

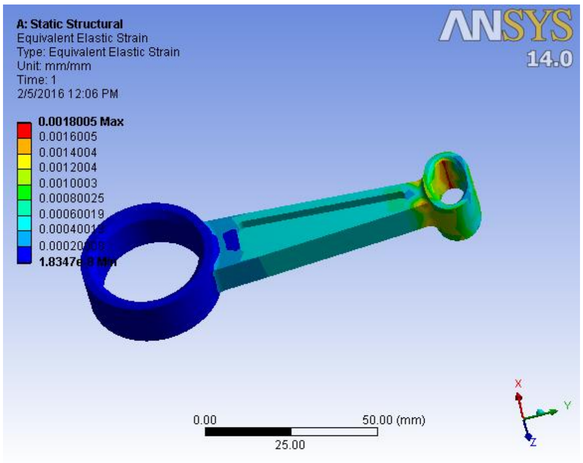
Material Properties	Carbon Steel	Aluminium 360	Aluminium boron carbide
Yeild strength (MPa)	415	172	300
Tensile strength(MPa)	540	317	485
Therotical factor of safety(N)	6	6	6
Density (kg/mm3)	7.86e-6	2.685e-6	2.95e-6
Youngs Modulus (GPa)	210	71	200

STRUCTURAL ANALYSIS OF CARBON STEEL

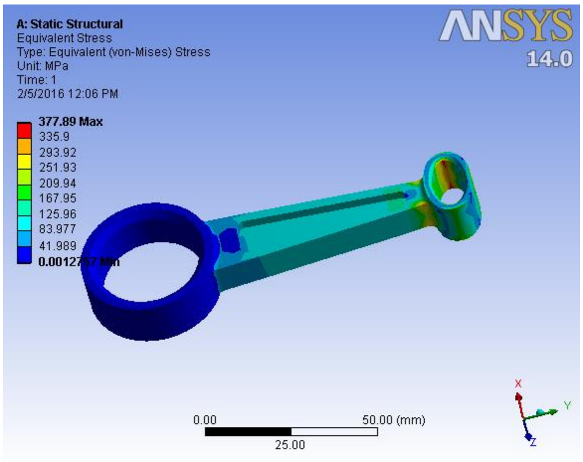
Deformation



Strain



Stress



STRUCTURAL ANALYSIS OF ALUMINIUM 360

Deformation

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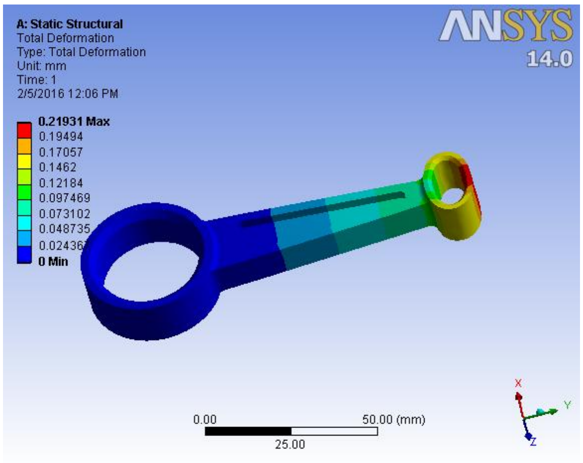

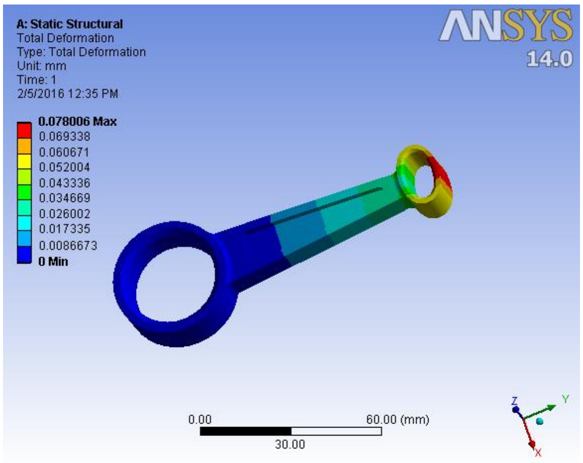

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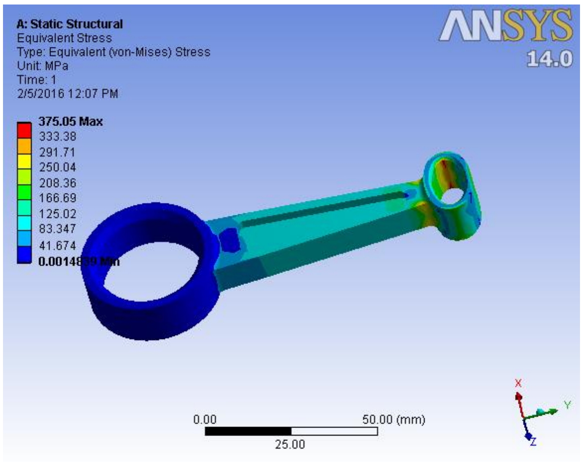

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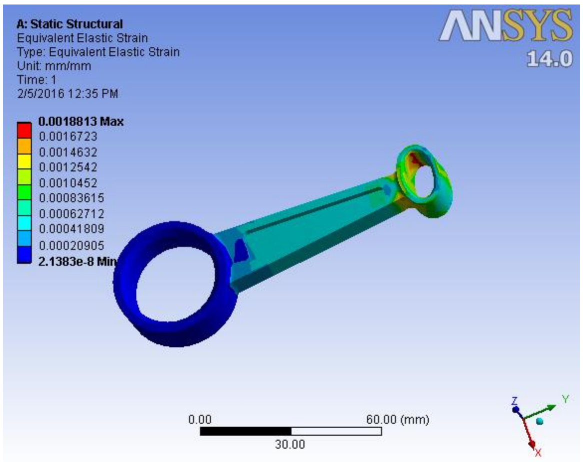

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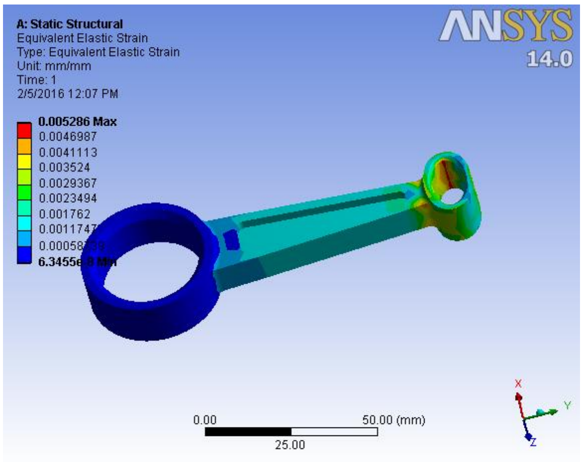

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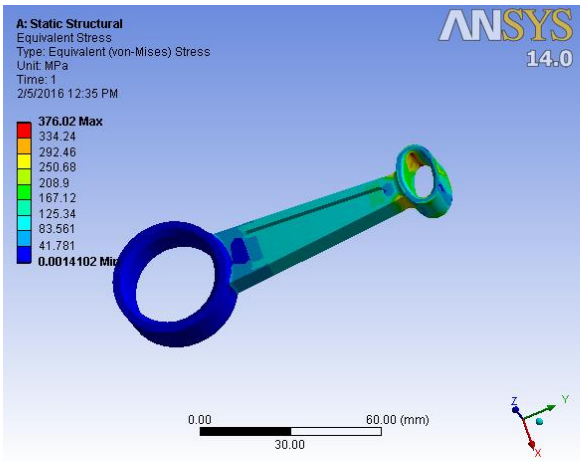

STRUCTURAL ANALYSIS OF ALUMINIUM BORON CARBIDE

Deformation

RESULTS

Material	Deformation (mm)	Strain (mm/mm)	Stress (MPa)
Carbon steel	0.074553	0.0018005	377.89
Aluminum 360	0.21931	0.005286	375.05
Aluminum boron carbide	0.078006	0.0018803	376.02

CONCLUSION:

As compared to above results the results taken into consideration for three materials i.e carbon steel, aluminum 360, aluminum boron carbide. The deformation of carbon steel is less as compared to aluminum 360 and aluminum boron carbide and strain in carbon steel is less than as compared to other two materials. Stress induced in aluminum 360 is less as compared to other two materials. All the values are within elastic limit hence as compared to all the results the aluminum 360 is most suitable for connecting rod.

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