TECH TALK

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TOLERANCES

Part 1

What are the effects of a good cooling system? Not only does it reduce temperature to avoid engine seizure but the performance and durability of the engine components can be improved if cooling is optimised. Tolerances between components vary when such elements change their temperature.

Expansion and contraction due to temperature variation

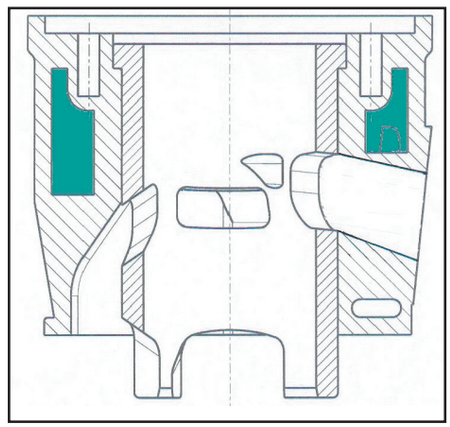
Any material changes its dimensions when it changes temperature. In most cases a solid when heated usually expands and when cooled it contracts. When determining the small gaps (tolerances) between two elements of the engine mounted together, we must always consider the deformation, expansion and contraction of such elements since when the engine is running the temperature of these elements will increase.

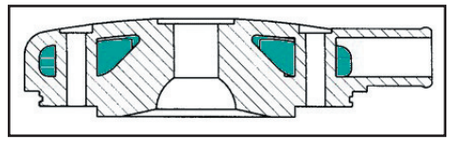
As an example the connecting rod big end and crankshaft axle are mounted to each other with a bearing positioned between the two. The tolerance of the three elements must be enough to permit free rotation of the parts but must not be too much or the elements will hit one another and the engine's geometry will be incorrect. For example, too high a tolerance will mean an imprecise piston position relative to the crankshaft and this will lead to combustion problems since ignition will occur when the piston is not at the height it should be.

Tolerance between piston and cylinder: engine performance

A simpler example of the importance of tolerances between engine components is in determining dimensions of piston and cylinder, two elements that must be perfectly matched together and that determine a great deal of engine performance and reliability. The tolerance between these two elements is usually set between 0.08mm and 0.12mm in 2-stroke, direct drive 100cc engines. Of course lower tolerances give better sealing of burnt gases that expand in the combustion chamber, giving a better push especially at low revs. However, this also leads to more friction between the two circular surfaces sliding one on the other and so reduces performance, particularly at high revs when the speed of the piston is of course higher. Very low tolerances also impart more stress to the two elements.

So when determining tolerances between cylinder and piston, or any other elements in contact and have a reciprocating movement, we must consider the temperatures they will experience. If the two elements are made of different materials such as a cast iron cylinder and an aluminium piston their expansion will be different. Also different shapes give differences in expansion.





The cylinder and the cylinder head (below) reach the highest temperatures so need the most cooling. In a water cooled system, liquid passes through the coloured areas

The elements that reach the highest temperatures are the cylinder head and the head of the piston. This is why the piston is not perfectly cylindrical but has a slightly conical shape. In fact the upper part of the piston, near the crown, expands more because it heats up more. When the engine runs the shape of the piston should be cylindrical. The cylinder also expands but since it is made of cast iron it expands less then the piston. This is also why the tolerance between piston and cylinder must not be too small. Such tolerance will change when the engine runs since cylinder and piston will expand differently. We will see in the next issue how small particles of material are shed from both elements and slide between the two surfaces, reducing even more the microscopic tolerance.

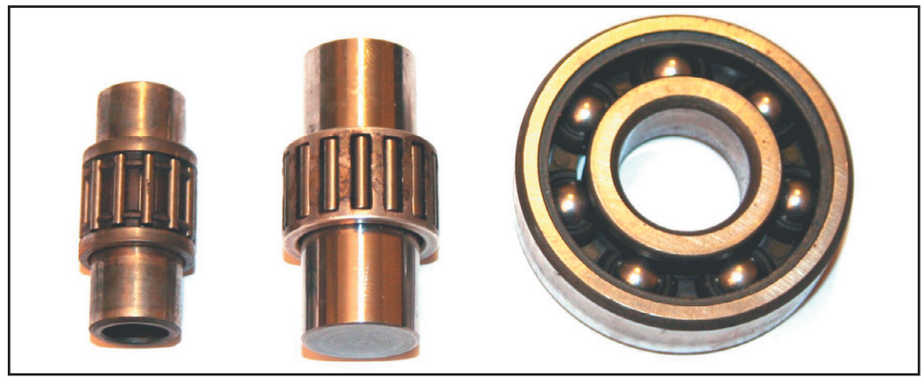
Bearings

Bearings have very precise tolerances and have an indication of the tolerance of the rotating elements inside the cage. C4 bearings are, for example, used in 2-stroke 100cc kart engines as crankshaft bearings. Tolerances will increase as the bearing becomes worn until the wear will be too much and the bearing will start working improperly. The bearing should be replaced in this case or if it has collapsed (the cage that holds the rotating elements breaks). If only one of the two crankcase bearings collapse the functioning bearing should still be replaced so that the tolerances on both bearings are the same.

Conrod

The conrod is a particularly expensive and important part. All the stress from pressure coming from the combustion chamber is transmitted to the piston and the conrod that, together with the crankshaft, transforms longitudinal force into rotational force. Design of the conrod is exceptionally precise so as to be extremely strong but with limited weight. Also the conrod big and small ends have extremely precise tolerances since they have to fit with 'open' bearings (with cylindrical rotating bodies) that work at extremely high revs and resist extremely strong and rotational forces. A poor tolerance would lead to bad positioning of the conrod with respect to the crankshaft and the piston. With too high a tolerance the conrod will hit the bearings making them wear faster and eventually break. Conrods wear during time, even though they can last a season, depending on how the engine is treated.

Sometimes big or small end bearing failures damage the internal surface of either of the two 'eyes' of the conrod. People sometimes machine the damaged surface to save money although this does not work well since the cast iron of the conrod surface is hardened (more than the internal part) and also, even more importantly, because tolerances change. Bearings with slightly different diameters are sold for this reason but to have an engine working well you should buy a new conrod. Old conrods will wear and break bearings faster, and what money you have saved initially will soon disappear in having to buy new bearings and rectifying breakages out on the track!



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