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A METHOD FOR PERFORMING QUALITY COMPARISONS OF RZEPPA JOINTS

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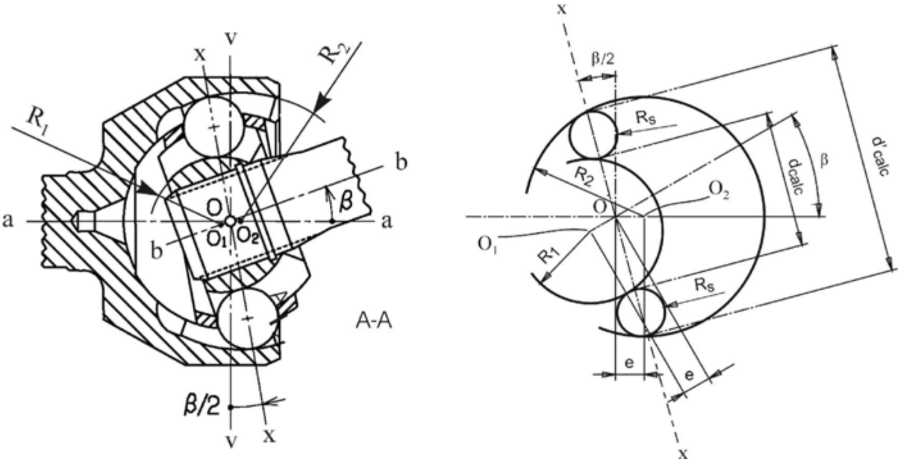
ABSTRACT
In the present work a methodology of metrological kind is suggested. The procedure has been developed to give information on the relative quality between two or more standard sets of Rzeppa joints made up by different factories. The methodology suggested is based on dimension and hardness evaluations. The main aim of the dimensional evaluations is the tolerances check that characterize the grooves of the inner and outer races. The hardness evaluations are considered with reference to the tribological aspects. In order to perform a position analysis of the inner and outer races in relation to the six spheres, a suitable CAD model has been made up. This model is essential because it gives the greatest change of certain nominal distances that must be measured versus the axes angle of the inner and outer races. The results obtained in relation to two sets of joints nominally of the same kind but manufactured by two different factories are presented.
Keywords: Rzeppa joint, quality, metrology, test, CAD

1. INTRODUCTION
The general spreading of the front-wheel drive cars has imposed the utilisation of Rzeppa constant-velocity joints [1-3] in almost all the automotive industries. This kind of joints has been studied enough, even if its kinematics and dynamics are very complex [4-6]. In any case, from an industrial point of view, some specialized factories produce different typologies of these joints for various kind of cars. These factories compete the one against the other, and therefore the important parameters for being the most successful commercial are quality and cheapness for the same joint manufactured. In relation to this aspect it is important to fix which joint has the higher reliability in comparison with other ones. This kind of evaluation can be certainly performed by a statistical analysis relative to samples of the joints tested. Nevertheless the evaluation of the joints characteristics can be highly expensive. As a matter of fact long and expensive road tests should be necessary to consider the factors that act during the usual working of a Rzeppa joint with certainty,. These tests should be performed by using the same kind of cars. On each car under test should be assembled the joints manufactured by the different factories. These kinds of tests could be very reliable because they really consider the working conditions of the joint. Unfortunately, in relation to the reasons previously mentioned, they are barely proposable, particularly from the joints’ reseller point of view. With reference to this problem, in the present work a methodology of metrological kind is suggested to give some information about the relative quality of two or more series of constant velocity Rzeppa joints.



(a) (b)

Figure 1. (a) Radii R_1 and R_2 of the grooves defined in the inner and outer races of an Rzeppa constant velocity joint; (b) distances dcalc and d'calc evaluated by the CAD model.

2. METHODOLOGY OF COMPARISON

The procedure considers two main steps: i) dimensional and ii) surface hardness measurements. The first ones allow us above all to check the tolerances of the grooves that have been cut in the inner and outer races of each joint. The second ones are considered in relation to the tribological aspects. With reference to the dimensional check, we observe that these joints are usually produced by using manufacturing tolerances lower or equal to 0.05 mm [3]. In this way a functional adjustment of the various parts of the joint in contact the one with the other can be spontaneously obtained even if they have relative positioning mistakes (a typical error is the poor incidence of the rotation axes associated to the outer and inner races of the Rzeppa joint, i.e. as a matter of fact these axes are skew). Then, since the above-mentioned tolerance value is applied in particular to the dimensions that define the functional clearances between the balls and the correspondent grooves, the experimental evaluation of these clearances is meaningful. The clearances measured represent a fitness index of the manufacturing and consequently of working of each joint. In fact we observe that if the clearances experimentally measured are too different than 0.05 mm, the joint functionality (for example, versus its life, quietness, vibrations, etc.) could not correspond with that one relative to the reference joints. These reference joints are those that have already proved a correct working. In relation to these remarks, the methodology suggested considers the utilization of a CAD model for performing displacement analyses of the system consisting of balls, inner/outer race, and cage of each joint. With reference to the axial section of a generic Rzeppa joint [see Fig. 1(a)], this CAD model allows us to evaluate the distances d_{calc} and d'_{calc} showed in Fig. 1(b) versus the angle β. β is measured between the two rotation axes *a-a* and *b-b* of the outer and inner races, respectively. d_{calc} represents the minimum distance between the surfaces of the balls pair set one in front of the other. On the contrary, d'_{calc} defines the maximum distance between the above-

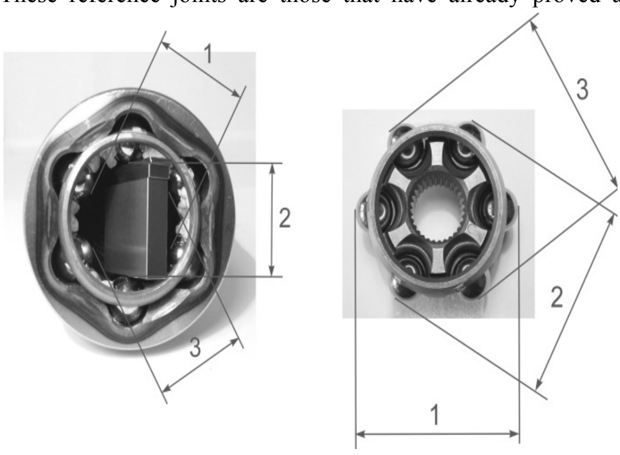


Figure 2. Measurements repeated of (a) d_{mis} and (b) d'_{misc}

mentioned two surfaces. Practically, we consider the distances between parallel planes pairs. These planes are tangent to each balls pair diametrically positionated. The CAD model illustrated in Fig. 1(b) shows the geometry of the nominal contact among the balls and the external/internal grooves. In the usual productions the eccentricity e [see Fig. 1(b)] is not greater than 3 mm and β varies from –20° to +20° (for Rzeppa joints the steering angle is about equal to 40°). By using these values, when $-20\ ° \leq \beta \leq 20\ °$, the CAD model proves that the changes of d_{calc} and d'_{calc} are always lower or equal to 0.01 mm. Consequently, if the experimental measurement of d_{calc} and d'_{calc} gives values whose change is about equal to 0.05 versus $-20\ ° \leq \beta \leq 20\ °$, it is reasonable to consider that the correct manufacturing tolerances relative to the external/internal grooves of the joint have been met. Therefore, indicated by d_{mis} and d'_{mis} the distances measured d_{calc} and d'_{calc}, respectively, the fitness of the joint tested can be evaluated with reference to the value experimentally obtained for the same d_{mis} and d'_{mis}. These two distances are measured by Johansson gauge blocks [see Fig. 2(a)] and micrometer gauge [see Fig. 2(b)], respectively. From the knowledge of the d_{mis} and d'_{mis} values, the computation of the clearance between balls and inner/outer grooves is possible. If the joint tested has been correctly manufactured, in general two conditions have to be met: i) the above-mentioned clearance has not to be greater than 0.05 mm and ii) the same clearance has not to be too lower than 0.05 mm. Moreover, in order to define a straight fitness comparison between the joint tested and the reference one, the maximum and minimum clearances should be as close as possible to those measured for the reference joint. We can observe that the diameter change of the balls is always lower than 0.01 mm. Consequently the measurement performed by Johansson gauge blocks is a valid index of the external grooves manufacturing accuracy. Similar remarks are effective with reference to the internal grooves in relation to the experimental measurement of d'_{mis} performed by the micrometer gauge.
Table 1 shows an example of d_{mis} and d'_{mis} measurements for a joint belonging to one of the two sets that have been compared in the case study. The procedure proposed considers measurements repeated to perform statistical analyses for evaluating the results reliability. In Table 1 the values of some statistical parameters relative to the quantities d_{mis} and d'_{mis} have been reported.

Table 1. Statistical parameters evaluated for dmis , d'mis , and dSF for a Rzeppa joint.

d_{mis}						
d_{MINmis} [mm]	37.385	$I = \{d_{MINmis}, d_{MAXmis}\}$	ΔI [mm]	d_{Mmis} [mm]	S_{dmis}	C_{Sdmis}
d_{MAXmis} [mm]	37.425	{37.385,37.425}	0.04	37.4139	0.0159474	0.0426244
m_2	m_3		m_4	a_3		a_4
0.000254321	-3.262×10-6		1.15839×10-7	-0.804287		1.79098
d'_{mis}						
d'_{MINmis} [mm]	*68.97*	$I' = \{d'_{MINmis}, d'_{MAXmis}\}$	$\Delta I'$[mm]	d'_{Mmis}[mm]	S'_{dmis}	C'_{Sdmis}
d'_{MAXmis} [mm]	69.01	{68.97, 69.01}	0.04	68.99	0.0149071	0.0216077
m'_2	m'_3		m'_4	a'_3		a'_4
0.000222222	-1.33333×10-6		7.55556×10-8	-0.402492		1.530000
d_{SF}						
$d_{MIN\,SF}$ [mm]	*15.87*	$I'' = \{d_{MIN\,SF}, d_{MAX\,SF}\}$	$\Delta I''$[mm]	$d_{M\,SF}$ [mm]	S_{dSF}	C_{SF}
$d_{MAX\,SF}$ [mm]	15.88	{15.87, 15.88}	0.01	15.8767	0.00471405	0.0296917
m_{SF2}	m_{SF3}		m_{SF4}	a_{SF3}		a_{SF4}
0.0000222222	-7.40741×10-8		7.40741×10-10	-0.707107		1.500000

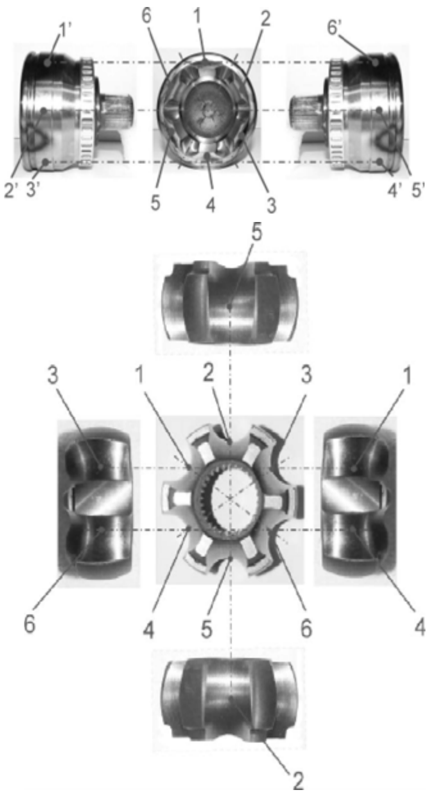


Figure 3. The twelve points where the hardeness measurements have been performed on (a) the outer and (b) inner races.

In relation to d_{mis} the following parameters were computed: d_{MINmis} = minimum value measured, d_{MAXmis} = maximum value measured, I = dimensional range, ΔI = maximum change, d_{Mmis} = average value, S_{dmis} = mean square deviation, C_{Sdmis} = dispersion coefficient, m_2 , m_3 , m_4 = moments of the second, third, and fourth order, respectively. Similarly, in Table 1 the same values, but relative to d'_{mis}, have also been reported. The correspondent symbols are equal to those used for d_{mis}, but an apostrophe has been added to them. Further evaluations of the previous statistical parameters have been performed for the six balls diameter d_{SF}. Table 1 reports these parameters denoted by the correspondent symbols $d_{MIN\ SF}$, $d_{MAX\ SF}$, I'', $\Delta I''$, $d_{M\ SF}$, S_{dSF}, C_{SF}, m_{SF2}, m_{SF3}, m_{SF3}, a_{SF3}, and a_{SF4}. In relation to the hardness, Fig. 3 shows the points where we can perform the measurements on the outer and inner races of each joint. Since the utilization of a Rockwell durometer is considered, the accessibility of its indenter is possible only to test the grooves of the inner race. In order to evaluate the hardness of the outer race grooves, we can consider the points where each groove starts. In Fig. 3(a) these points are denoted by the numbers 1, 2, 3, 4, 5, and 6. The methodology proposed considers the computation of statistical parameters analogous to those evaluated for d_{mis}, d'_{mis}, and d_{SF}. If the hardness measured for the joint tested are higher or equal to those of the reference joints, the evaluation concerning this aspect an the relative implications (i.e. abrasion and wear resistance, joint life, maintenance, etc.) will be positive.

3. CONCLUSIONS

The methodology suggested allows us to obtain a careful information concerning of Rzeppa joints fitness in a short time and by using a cheap equipment. In particular the relative quality between two or more classes of joints can be evaluated. The procedure proposed has been shown with reference to a case study represented by two sets of Rzeppa joints whose relative fitness was to evaluate (the sets have been manufactured in Italy and China, respectively). The test results show that in relation to the aspects considered, the quality of the two products sets is practically equivalent.

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