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MATERIALS FOR AUTOMOBILES
By ELWOOD HAYNES, KOKOMO, IND.
Non-Member

Since the first attempt to build automobiles, early in the 90's, experimenters have had difficulty in getting materials suitable for the purpose. Steel of high tensile strength was employed but the results were not satisfactory. Lower carbon steels were tried, but they lasted only a few weeks, or months, and then broke short off. Swedish iron did not break, but when the first hard bump was encountered it took a set and the wabbling rear wheels indicated what had happened. Finally a steel of moderately low carbon was introduced which gave only fair results, and if the car was driven for any length of time over rough roads, this also crystallized and broke off.

NICKEL STEEL

2 In 1899 a nickel steel axle was introduced into a machine by Messrs. Haynes & Apperson, and the car made successfully a trip from Kokomo, Ind., to New York, a distance of about 1000 miles, without serious breakage of any kind. This axle was made by the Bethlehem Steel Co., of Bethlehem, Pa., and so far as is now known, was the first material of this kind ever used in an automobile. Nickel steel was used in the axles of cars of this construction for about five years, and not a single case of breakage occurred during that period. Not only was this steel found to be practically free from crystallization, but it possessed a very high elastic limit—about 70,000 or 80,000 pounds—and a tensile strength of over 100,000 pounds, with an elongation of about 15 or 20 per cent.

3 Soon afterward nickel steel was introduced into the construction of driving chains and those chains showed great superiority over the ones formerly made of ordinary steel. When the sliding gears were first used on the automobile for the purpose of changing the gear ratio between the motor and rear axle, trouble was again encountered in breakage.

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Gears were made of the best kinds of tool steel without success. The ends of the teeth would break off when an attempt was made to throw them suddenly into engagement by means of the shifting levers. Trouble of a very serious nature resulted from this, as pieces of the broken teeth would get into the other gears, thus causing them to break, and sometimes the entire train of gears would be almost ground to pieces on account of the breakage first of one gear and then of another.

4 Machinery steel, case hardened, was tried, and while this gave better results, it was by no means satisfactory. The injury and breakage of sliding gears were taken as a matter of course, and almost every person possessing a car equipped with these gears expected sooner or later to make a number of replacements.

NICKEL CHROME STEEL

5 It was finally discovered that an alloy consisting of iron, nickel, and chromium possessed most remarkable properties. Not only could the steel be hardened by heating to redness and quenching in oil, but it could be given a considerable amount of toughness at the same time by drawing the temper somewhat after the first hardening. If the steel was properly made and afterward properly treated, it was found to be almost impossible to break one of the teeth in a 6-pitch gear by means of a heavy hammer. So successful were these gears that they rendered it possible to run an entire season sometimes without the breakage or serious injury of a single tooth. Front axles, steering knuckles, and other important parts requiring high elasticity were made of this steel in certain cars with very good results.

6 It has been found that the manufacturing and working of nickel chrome steel requires great care, as there seems to be some tendency toward segregation when the steel is in the process of making, which gives rise to hard and soft spots in the finished metal. If an attempt is made to manufacture gears from material of this character, it will be found that some of the teeth are extremely hard while others are just about the right hardness. On the other hand, even if the steel is of uniform composition and texture throughout, it will not stand very great variation of temperature without danger of injury, since it is very sensitive to heat treatment. When properly made and properly treated, however, it is perhaps the most resistant substance to shocks and blows yet produced.

7 The following may be taken as a test of high quality nickel chrome steel made by the Krupp Company, of Essen, Germany. It will be noted that much depends upon the treatment of the steel:
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DIMENSIONS OF TEST BARS, 5.91 IN. LONG AND 0.59 IN. DIAM.

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>Slightly hardened</th>
<th>Greater deg. of hardness.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elastic limit, lb. per sq. in.</td>
<td>86,909</td>
<td>148,072</td>
<td>193,589</td>
</tr>
<tr>
<td>Tensile strength, lb. per sq. in.</td>
<td>111,943</td>
<td>155,326</td>
<td>221,325</td>
</tr>
<tr>
<td>Elongation, per cent</td>
<td>14.5</td>
<td>9.1</td>
<td>7.7</td>
</tr>
<tr>
<td>Contraction, per cent</td>
<td>64.0</td>
<td>55.6</td>
<td>46.2</td>
</tr>
</tbody>
</table>

It will be noted from the above tests that under the hardening treatment the tensile strength rises rapidly, and the same may be said of the elastic limit. The contraction of area does not suffer so much as the elongation. The comparatively small loss in contraction of area is a good sign, since it indicates that the texture of the steel has been well preserved under treatment.

8 Plain nickel steel containing a very small per cent of carbon is also a good safe material for automobile work. The following may be taken as an example of a mild low carbon nickel steel:

- Elastic limit, 65,146; tensile strength, 81,561; elongation, 23.9 per cent; contraction of area, 71 per cent.

9 It will also be observed from this that while the elastic limit is quite low as compared with the nickel chrome steel, it is high as compared with ordinary carbon steel; and that the elongation and contraction of area are very high indeed, indicating a very safe material for almost any construction. This material not only possesses these excellent properties, but resists dynamic stress remarkably well—in fact if the dynamic stresses are not too close to the elastic limit of the steel, it will preserve its strength and quality for an indefinite time. The following tests indicate the quality of this material as compared with carbon steel, the samples being tested under combined torsion and vibration.

- Carbon steel, 15,000 vibrations; nickel steel, 34,000,000 vibrations, —not broken.

VANADIUM STEEL

10 Besides the steels already mentioned, there is another which is now attracting considerable attention; namely, that produced by adding a small quantity of vanadium to a nickel steel or chrome steel. Since vanadium has until recently been classed among the very rare elements, it may perhaps be in place to mention a few of its properties. It is prepared from the chlorid V Cl₂, which is reduced by means of a current of hydrogen gas, the chlorid being heated while the reduction is taking place. Simple as this process may seem, it is one of the most
difficult known to chemists, and it usually requires three or four days to prepare a fraction of an ounce of the metal by this process. Until quite recently this element and its compounds, owing to their rarity, were very expensive, but we are now assured by the American Vanadium Company that a sulphid of vanadium has been discovered in an immense quantity in the Andes mountains of South America, and that they are prepared to furnish the metal in the form of a ferro alloy, known as ferro-vanadium, in any quantity desired.

11 This ferro-vanadium contains about 20 per cent of the latter metal, and is readily incorporated with the iron or steel during the melting, either in the open-hearth or crucible process. Mr. J. Kent Smith, who has given the subject of vanadium steel much attention, advocates the open-hearth process as preferable to the crucible process for the making of this steel. This steel possesses most remarkable qualities, notwithstanding the small quantity of vanadium which it contains. One of these is the closeness with which its elastic limit approximates its tensile strength, and since the former quality is the one in which the greatest dependence is placed, this is a very desirable characteristic. The sharp contraction of area, also a characteristic of this steel, together with the silky fracture it usually presents, is also a strong indication of the splendid quality of this material. Moreover, the fracture is nearly always of this quality, even though the steel has been highly tempered.

12 It is a rather remarkable fact that the vanadium alone or with carbon does not give much character to the iron or steel, but when a third element is introduced, such as nickel or chromium, the characteristics of the steel are changed for the better. Whether the vanadium acts as an essential element in the composition of the steel or principally as a purifier is not fully known; it has been found, however, that a certain amount of the vanadium introduced (about \( \frac{1}{2} \) per cent), must remain in the steel in order to give it its characteristic properties. Vanadium, however, has a strong affinity for nitrogen as well as for oxygen, and it may be that it acts as a purifier of the steel by combining with minute quantities of nitrogen gas, which might otherwise be occluded in the steel and thus interfere with its compactness and strength.

13 It will readily be seen that the high elastic limit, strong contraction of area and splendid silky fracture, together with the large number of vibrations which the steel endures under dynamic stress, most strongly recommend this steel as almost ideal for many parts of the motor car. The writer has made some experiments in the forging, and found that it works well under the hammer, though it must not be
allowed to become too cold or it will resist pounding to a remarkable degree. It is not readily injured under the forging hammer, provided due care is taken not to heat it too rapidly. Another valuable property of the steel is the fact that it machines more readily than nickel chrome steel—in fact, more readily than plain nickel steel.

BRONZE AND OTHER ALLOYS

14 The use of bronzes in the motor car must necessarily be restricted to parts requiring low rigidity, and usually also moderate strength. While it must be admitted that samples of bronzes can be made that approach closely to fairly good grades of steel in tensile strength, elastic limit, and contraction of area, it must also be remembered that the modulus of elasticity of iron and steel is about 28,000,000 pounds, for example, while that of bronze is only about 15,000,000 pounds. This means that a bar of bronze of a given size and form under given conditions will deflect nearly twice as much under the same load as a similar bar of iron or steel. In most parts of the car this feature is objectionable, since changes of alignment are likely to occur, unless the parts which are made of this material are especially well designed.

15 Notwithstanding the above objection the readiness with which bronze lends itself to the production of castings of various parts, and its freedom from crystallization under dynamic stress has led to its introduction into many of the minor parts of the motorcar, such as small hand levers, carbureters, tubing, crank cases, gear cases, etc. In general, it may be said that it is suitable for the small levers such as those used for controlling the sparking mechanism, carbureter, etc. Another use for this metal is in bearings, although these require a decidedly different composition from that used for levers, crank cases, and like parts.

16 The parts requiring strength are usually made from nickel bronze, phosphor bronze, manganese bronze, or aluminum bronze, while the bearing bronzes are composed usually of lead, tin, and copper in various proportions. Under this latter head come also the so called babbit metals which vary greatly in their composition, some of them being composed of lead, copper, tin, and antimony; others of lead, tin, zinc, and antimony, and still others of lead, tin, and antimony. It is not the purpose of the writer to discuss the merits of these various bearing metals, since a number of very good ones can be readily obtained on the market.

17 Beside the above alloys, pure copper is used to a considerable extent in the construction of radiators, gasoline tanks, etc. It is well
adapted for the construction of radiators, since it can easily be soldered; is one of the best conductors of heat, and is readily formed into almost any shape on account of its malleability, ductility, and comparative softness.

ALUMINUM

18 Aluminum is now used very largely in automobile construction, and it is a significant fact that it was first introduced into the automobile in America, though the French used it quite early to some extent for a few minor parts of their machines. Pure aluminum is used only for a few special purposes, and even then to a limited extent—most notably for tubing and radiators. It is quite well adapted for the latter purposes in many respects, but the comparative difficulty experienced in soldering it is a drawback. On the other hand, when alloyed with copper or some other metal giving it increased hardness and elasticity, it is well adapted for various purposes such as seats, gear cases, crank cases, dashes, and various other parts of the car. Its extreme lightness, together with the ease with which it may be machined and the facility with which it may be cast, renders it very useful for many parts of the machine.

19 An alloy of zinc and aluminum seems to have considerable rigidity and elasticity, as well as quite high tensile strength. It is also cheaper than the aluminum copper alloy, but experiments made by the writer indicate that this alloy is not safe if subjected to repeated vibrations, since it seems to fatigue quite rapidly and sooner or later breaks off short. For example, a ¼-inch square bar made of an alloy of aluminum and zinc withstood only about 15,000 vibrations before breaking, while an alloy of copper and aluminum withstood 1,600,000 vibrations of the same amplitude and frequency without breaking or showing any signs of injury except a very slight set. Aluminum also forms a very light alloy with magnesium, which, however, is too expensive for ordinary use and is somewhat difficult to handle in quantity. A number of other alloys of aluminum have been prepared, and to some extent used in automobile construction—the most notable perhaps of which is an alloy of tungsten and aluminum, which has been used to a considerable extent abroad, but is not used in American cars so far as the writer is aware.

RECAPITULATION

20 From the foregoing it may be said that the following substances have proved suitable for the various parts of the automobile:
a For rear live axles, nickel steel containing from 4 per cent to 5 per cent nickel and less than 0.3 per cent carbon.
b For front axles, steering knuckles, propeller shafts, etc., vanadium steel.
c For sliding gears, nickel chrome steel hardened throughout, or mild nickel steel case hardened.
d For crank shafts, nickel steel or vanadium steel.
e For frames, low carbon open-hearth steel, mild nickel steel or nickel chrome steel.
f For nearly all other parts of the car, such as hand levers, tubing, etc., a good open-hearth steel of comparatively low carbon—say 0.4 per cent or under—is of suitable quality, since there is no advantage gained by using high class steels for these purposes for the reason that the rigidity of these parts is of prime importance, and in order to make them sufficiently rigid, they must be made much more than sufficiently strong; therefore, since all steels are practically equal in rigidity, one steel is, broadly speaking, as good as another for these parts.

21 The use of bronze should be restricted largely to minor parts; the reducing gear wheels, small levers, etc., can be made of phosphor bronze, while the bearings should be made of some good composition bronze—an alloy of copper, lead, tin and zinc answers well for this purpose, but the main bearings for the engine, such as the crankshaft, crank pins, etc., should be made of a special bearing metal, which is very firm and at the same time will not injure the crankshaft in case the lubrication becomes deficient. The crank case of the motor, the gear case, and other similar parts may well be made of aluminum, since it is light, strong, and easily cast into the proper shape. Steel would answer for the above parts if it could be conveniently worked into the proper form.

22 It will be noticed from the foregoing that the most progressive automobile builders have spared neither pains nor expense in obtaining the very best materials that can be produced, because in order to obtain the highest results in automobile construction, it is necessary that material of superior quality shall be used for certain parts of the machine. Perhaps there is no form of construction that taxes the ingenuity of its builders more severely than the building of a good automobile. Those who are versed in mechanical matters and who know the sizes of parts generally used for heavy stress, often marvel at the strength and endurance of the modern automobile. Factors of safety must be reduced to the minimum in nearly every part of the
machine or excessive weight is sure to occur. Many high class machines weigh less than 70 pounds to the horse power, passengers included. Of course it is not expected that the motor shall be used constantly at anything near its maximum horse power—\( \frac{1}{10} \) of its brake horse power is enough for almost any automobile motor when in daily use; high power is simply intended to meet emergencies, but the material throughout the machine must be strong enough to withstand any stress momentarily applied.

23 The following table gives approximately the strength of various materials used in automobile construction:

<table>
<thead>
<tr>
<th>Material</th>
<th>Modulus of rigidity</th>
<th>Elastic limit</th>
<th>Tensile strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum alloys</td>
<td>8 to 11 million</td>
<td>10M to 15M</td>
<td>20M to 30M</td>
</tr>
<tr>
<td>Phosphor bronze</td>
<td>12 to 14 million</td>
<td>20,000</td>
<td>30,000</td>
</tr>
<tr>
<td>Manganese bronze</td>
<td>15 million</td>
<td>35,000</td>
<td>50,000</td>
</tr>
<tr>
<td>Aluminum bronze</td>
<td>15 million</td>
<td>50,000</td>
<td>75,000</td>
</tr>
<tr>
<td>Wrought iron</td>
<td>28 million</td>
<td>30,000</td>
<td>40,000</td>
</tr>
<tr>
<td>Mild open hearth steel</td>
<td>28 million</td>
<td>40,000</td>
<td>60,000</td>
</tr>
<tr>
<td>Tool steel</td>
<td>29 million</td>
<td>80,000</td>
<td>110,000</td>
</tr>
<tr>
<td>Nickel steel</td>
<td>28 million</td>
<td>80,000</td>
<td>110,000</td>
</tr>
<tr>
<td>Nickel chrome steel</td>
<td>30 million</td>
<td>160,000</td>
<td>180,000</td>
</tr>
<tr>
<td>Vanadium steel treated</td>
<td>30 million</td>
<td>220,000</td>
<td>228,000</td>
</tr>
</tbody>
</table>

All of the above materials stand well under dynamic stress with the exception of the tool steel, which should not be used for this purpose.