INTRODUCTION
The development of the rubber industry and advent of synthetic rubbers have given rise to numerous rubber compounding agents contributing to improvements in the performance and quality of rubber products and the streamlining of manufacturing processes.

One such compounding agent is factice. Initially used as an inexpensive substitute or extender for natural rubber, it changed in function to a softener and processing aid after the introduction of synthetic rubber. This article reviews the properties and utility of factice, illustrated with examples of usage.

What is Factice?
A factice is generally a solid formed by crosslinking animal or vegetable oil with sulphur, etc. Factices are grouped into three types according to the crosslinking agent used: sulphur factice, sulphur chloride factice and sulphur-free factice (Table 1).

A sulphur factice can be obtained by adding sulphur \( (S_\text{8}) \) to the oil and heating, while a sulphur chloride factice is obtained by adding sulphur chloride \( (S_\text{2}Cl_\text{2}) \) and reacting at ambient temperature. Sulphur-free factice is obtained by reacting with isocyanate or organic peroxide, for example.

The oils used are vegetable oils, notably rapeseed oil, soybean oil and castor oil, and animal oils such as fish oil.

Although mineral oil and plasticisers are sometimes used as compounding agents, calcium carbonate or the like is commonly added as a stabiliser in the case of sulphur chloride factice.

NOMENCLATURE
A factice is to all appearances a rubber-like elastic material. In the days of expensive natural rubber, when factices served as rubber substitutes or extenders, they were called “rubber substitutes” in the UK and “les caoutchouc factices” (man-made rubbers) in France. The term factice has now established itself internationally though in the USA “vulcanized vegetable oils” is used, while in Japan the term “sabu (sub)”, a contraction of the British name, is generally preferred to “fakuchisu (factice)”. Based on the appearance and colour of the product, sulphur factice is also called “dark/brown factice (kurosabu)” and sulphur chloride factice is called “white factice (shirosabu)” or “amber factice (amesabu)”.

Table 1. Classification of factices

<table>
<thead>
<tr>
<th>Type (common term)</th>
<th>Crosslinking agent</th>
<th>Main raw materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur factice (brown factice, etc)</td>
<td>Sulphur ( (S_\text{8}) ), hydrogen sulphide, etc</td>
<td>Rapeseed oil, soybean oil, castor oil, etc</td>
</tr>
<tr>
<td>Sulphur chloride factice (white factice, amber factice)</td>
<td>Sulphur monochloride ( (S_\text{2}Cl_\text{2}) )</td>
<td>Rapeseed oil</td>
</tr>
<tr>
<td>Sulphur-free factice</td>
<td>Isocyanate, organic peroxide, etc</td>
<td>Rapeseed oil, soybean oil, castor oil, etc</td>
</tr>
</tbody>
</table>
The Japanese dictionary of rubber terms Gomu Yougo Jiten [1] states that “A factice is vulcanised oil obtained by adding sulphur to vegetable oil and vulcanising, or by adding sulphur chloride in the cold. Factices obtained with sulphur are brown (dark/brown factice) while those obtained by adding sulphur chloride are white or pale yellow (white factice or amber factice) and tend to retard cure. Used as softeners, processing aids, etc”.

The Japanese handbook of rubber and plastics compounding chemicals, Binran Gomu-Purasuchikku Haigou Yakuhin [2], comments that “Factice has been used as a softener, processing aid and extender since the earliest days of the rubber industry, but its defining characteristic is that it imparts softness to rubber products, a softness remaining virtually unaffected by change in temperature. It prevents sticking to rolls during mixing, shortens the mixing time of other compounding agents, and improves workability in sheeting and extrusion; at the same time it is highly effective in preventing shrinkage and loss of shape in the uncured compound. It also acts as a cure accelerator, and has many beneficial effects such as preventing the bloom of compounding agents”.

HISTORY

Factice has a surprisingly long history. According to the monograph “Sabu Dangi (Discourse on Rubber Substitutes)” [3], sulphurized linseed oil and sulphurized balsam had been produced for medicinal purposes by medieval alchemists; and it seems elastic analogues of rubber were already present in Europe in the 1730s at the time the first South American rubber trees arrived [4]. In the 1850s first sulphur chloride factice and then sulphur factice were invented in Britain and as quality improved these began to find application in the rubber industry [4].

Although imports from Germany and France were being used in Meiji era Japan in 1907, domestic production only became established in the Taisho era, in the 1910s. More than 20 manufacturing plants are said to have existed at that time [5, 6].

In 1962 a symposium entitled “Factice as an aid to Productivity in the Rubber Industry” was held in the UK. Lectures and research communications by experts were presented on the history, production and chemistry of factice, along with methods of using factice for NR, SBR and other synthetic rubbers. The proceedings, inclusive of question and answer sessions, were recorded in a 133 page bound volume [7].

Much has since changed, and it is now recognised that, besides improving the processability of rubber and aiding improved productivity in its role as a processing aid, factice is of value in raising the quality of rubber products.

CHEMICAL STRUCTURE

The main constituents of the oils and fats used for the production of factice are triacylglycerols, in which three fatty acid molecules are combined with glycerol. A three dimensional network structure is formed by bridging between the main chains of the fatty acids. According to Urabe’s review of crosslinking [8], 5-7 atoms of sulphur per molecule of the oil participate in intramolecular and intermolecular crosslinking in a sulphur factice. In a sulphur chloride factice, on the other hand, three sulphur atoms participate in intermolecular crosslinking and 3 chlorine atoms participate intramolecularly.

THE THREE MAIN CHARACTERISTICS OF FACTICE

Factices are elastic materials with a three-dimensional network structure and have no melting point. They hence have the following characteristic features not found in other compounding agents.

Non-thermoplasticity

Since the properties of factices do not change significantly at the rubber vulcanisation temperature, compounds incorporating factice suffer less deformation due to heat.
and afford enhanced flow in continuous vulcanisation or high-speed, high-temperature cure injection moulding [3, 9]. Moreover the shape and dimensions of rubber compounds can be preserved and shrinkage prevented.

Flow under pressure
Because of its elastic properties, factice deforms under pressure, acting as a lubricant and promoting the flow of rubber compounds. As shown in Figure 1 [10], the factice particles in rubber-factice compounds are spherical before entering the roll gap but flatten where pressure is applied inside the roll gap, thereby improving rubber throughput, and return to their original spherical shape on emerging from the roll gap, serving to smooth the rubber surface.

Oil absorbency
The factice in rubber compounds absorbs liquid compounding agents (oil, plasticizer, etc), and is able to suppress tack and bleed.

The amount of oil absorbed by factices has been reported [11]: the results are summarised in Table 2. Tests on four different liquids showed that all the factices absorbed more liquid than a calcium carbonate control.

 USAGE AND UTILITY
A number of examples of the uses of factice are given below.

Remediation of bleed phenomena
The effect on preventing oil bleed from non-sulphur-modified chloroprene rubber has been reported [12]. When the loading of process oil was increased without also using factice (brown factice), bleeding was observed and tackiness developed on the rubber sheet surface; in contrast, a 15 phr addition of factice eliminated bleed without sacrificing general properties, demonstrating a marked effect. The results are shown in Table 3.

Soft rubber compounding
To confer flexibility, much process oil, plasticizer, etc, is incorporated during the manufacture of soft rubber products. However, the additives can bleed, leaving the cured rubber tacky and blocking the abrasive surface when the product is buffed. It is reported that combining

![Figure 1. Behaviour of factice particles in a rubber compound [10]](image)

### Table 3. Oil-bleed preventative effect of brown factice [12]

<table>
<thead>
<tr>
<th>Brown factice/process oil</th>
<th>0/30</th>
<th>15/30</th>
<th>30/30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncured compound</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ML1+4</td>
<td>12.3</td>
<td>17.4</td>
<td>22.1</td>
</tr>
<tr>
<td>Scorch time t5 (min)</td>
<td>22' 45&quot;</td>
<td>21' 05&quot;</td>
<td>22' 15&quot;</td>
</tr>
<tr>
<td>Vulcanisation (150°C)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cured rubber</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>200% tensile stress (MPa)</td>
<td>0.78</td>
<td>0.78</td>
<td>0.78</td>
</tr>
<tr>
<td>Tensile strength (MPa)</td>
<td>10.2</td>
<td>12.5</td>
<td>9.7</td>
</tr>
<tr>
<td>Elongation (%)</td>
<td>887</td>
<td>902</td>
<td>888</td>
</tr>
<tr>
<td>Hardness (JIS)</td>
<td>24</td>
<td>26</td>
<td>25</td>
</tr>
<tr>
<td>Compressive set [%]*</td>
<td>38.5</td>
<td>32.0</td>
<td>41.9</td>
</tr>
<tr>
<td>Bleed of cured rubber**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Room temperature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 days</td>
<td>x</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>6 days</td>
<td>x</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>12 days</td>
<td>x</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>70°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 days</td>
<td>▲</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

Compound recipe: Non-sulphur modified chloroprene rubber 100, age resistor PAN 2, magnesia 4, MT black 10, process oil as above, brown factice as above, zinc white 5, accelerator ETU 0.5

* 70°C - 22 h

** O: no bleeding, ▲: slight bleeding, ▲: some bleeding effects, x: much bleeding
the additives with the use of factice to counteract this facilitates addition of liquid softening agents and prevents tackiness and grinder blockage [13].

While being a solid without a melting point, factice acts as a softening agent in its own right and hardness is reported to decrease by 1 on addition of 5 phr of factice to 100 phr of rubber [14]. Since large amounts are easily added, it is considered indispensable as a compounding agent in the production of soft rubbers [15].

**Improvement of feel and polishability**

The abradability of factice can impart special character to vulcanised rubber [3].

In the case of soft tennis balls [16], a characteristic surface texture and tactile sensation can be obtained by a post-cure polishing step. The smooth wear of factice accounts for a very large part of this, allowing the rubber to be given a soft finish unattainable in rubber sheet or sponge rubber.

In addition, a patent [17] has been filed claiming the improvement of polishability and processability in semiconductive rubber rollers by incorporating factice.

**Eraser (rubber eraser) compounding [18]**

Erasers are a leading example of factice usage. Although white factice in particular has high cleaning efficacy, it is brittle and difficult to use on its own. In actual compounds, therefore, rubber is used as a binder (Table 4). White factice is the most important starting material in the manufacture of erasers, and erasing performance is heavily influenced by factice quality and recipe content.

**Wetsuit compounding [19]**

It is important that the sponge rubber used for wet suits and the like is uniformly foamed and factice is claimed to be effective in assisting dispersion of the blowing agent. Compounding with factice improves the texture and feel of the sponge rubber.

**Examples of application to adhesive tape [20]**

An important property required of adhesive binding tape is that, at the same time as having minimal adhesive strength towards the bound item, the tape should be highly self-adhesive on its adhesive surfaces. It has been shown that if factice is incorporated, self adhesion can be increased while the tape adhesive strength is kept constant.

Special uses (resin cleaning (purging) material, die anti-fouling agent)

Factice has been used as a resin cleaning (purging) material [21, 22]. By incorporating factice in thermoplastic resins, it is possible to strip out and perhaps adsorb residual resin, etc, adhering to the screw or inner wall of the barrel of the resin extruder or injection moulding machine, in order to achieve a cleaning effect.

The aforementioned monograph [3] notes that the properties of factice lead to a non-fouling effect. The writer and co-workers [23] therefore conducted an investigation of 5-10 phr of factice compounded with various rubbers, the results indicating a die anti-fouling effect, in the light of which future application as a die antifoulant is anticipated [24].

**Other uses**

As examples where the oil absorption of factice is exploited, patents filings have disclosed that the bleed and bloom of age resistors can be prevented, and the anti-aging effect sustained, by applying a pretreatment such as hot mixing the rubber age resistor and factice [25, 26].

<table>
<thead>
<tr>
<th>Compounding agent</th>
<th>Type of eraser</th>
<th>Ordinary eraser</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Example 1</td>
<td>Example 2</td>
</tr>
<tr>
<td>Raw rubber</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>White factice</td>
<td>50</td>
<td>24</td>
</tr>
<tr>
<td>Softener</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>Zinc oxide</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Titanium white</td>
<td>10</td>
<td>5-10</td>
</tr>
<tr>
<td>Calcium carbonate</td>
<td>4.5</td>
<td>30-35</td>
</tr>
<tr>
<td>Sulphur</td>
<td>1.3</td>
<td>0.9</td>
</tr>
<tr>
<td>Organic accelerator</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Inorganic accelerator</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Abrasive</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
SUMMARY OF USAGE

Depending on compound formulation, the following benefits may be obtained by using factice as a processing aid, softening agent or dry plasticizer.

- A reduction in compound tackiness in roll operations.
- Faster dispersion of compounding agents such as filler and oil, due to the plasticising effect.
- Good dimensional stability and a smooth surface, due to reduction in die swell and calendrer shrinkage.
- Enhanced compound flow with faster rates of extrusion or injection moulding.
- Because the factice is a solid, a large amount can be added to produce a soft rubber product.
- The oil absorbency of factice prevents bleeding of liquid compounding agents.
- Since the compound resists extraction by oils and solvents, volume shrinkage can be reduced.
- The texture and feel of the cured rubber are improved.
- Ozone resistance and the electrical insulating properties give extended vulcanisate endurance.
- The polishability of the cured rubber is improved.

POINTS TO NOTE IN USING FACTICE

A number of points need to be considered when factice is used.

- To ensure good dispersion, the factice must be added at a very early stage of milling, i.e. while the rubber stock still has strong nerve, and thus incorporated under shear.
- Compounding with sulphur factice can adversely affect properties such as compressive set and tensile strength, depending on the phr added; and free sulphur in the sulphur factice may affect cure.
- Compounding with sulphur chloride factice requires caution in relation to delayed cure due to the presence of chlorine. Methods of countering this include: adding metal oxide, metal hydroxide, or an alkaline material such as an amine, at 10 wt% of the sulphur chloride factice; using a guanidine, aldehyde-ammonia, or aldehyde-amine vulcanisation accelerator; and curing at the lowest temperature possible.

CONCLUSIONS

Originating as a substitute for natural rubber, factice has transformed into a processing aid as the rubber industry has developed and offers unique features not seen in other compounding agents. Skilful exploitation of its utility should serve to improve productivity.

REFERENCES