MPC-6 "Effects of Melting and Processing Variables on Mechanical Properties of Steel"1
Properties of Extra Low Sulfur Engineering and Die Steels2

W. R. Warke.3 This paper is an interesting addition to the growing body of information documenting the benefits to be realized in terms of ductility, impact properties and fracture toughness through reduction of the sulfur content of steels to extra low levels. On the other hand, one is aware of the marked improvements in machinability which can be obtained through increased sulfur levels. Since dies made from these steels must be machined in generating the die cavity, I wonder if the author could comment on the relative machinability of these steels. A further general comment on the relative merits of reducing directability of mechanical properties by sulfur removal and by sulfide shape control would be appreciated.

Author's Closure

We wish to thank Professor Warke for his discussion. Our paper records the benefits of sulfur reduction for some higher carbon alloy steels and larger sections.

Sulfur at the 100 point level has well established machinability benefits but is intolerable in dies. Tool life tests at die hardness have a detectability level of approximately 15 points of sulfur. The steels investigated would have a 15 to 25 point sulfur reduction. Machinability loss would therefore be just above the detectability limit and is trade-off made for improved ductility.

Additions for sulfide shape control always first reduce sulfur and then reduce deformability of the residual sulfides. The consistency and required addition of the shape control elements depend much upon the initial levels of oxygen etc. which react before sulfur.

With high carbon steels, titanium or zirconium may form embrittling compounds with carbon and sulfur. Rare earths increase the sulfide volume and if in excess degrade cleanliness.

Injection, if prolonged to attain the desired sulfur, can result in teeming a cold heat with adverse cleanliness effects.

Heavy forgings permit no diversion if the desired end result is not obtained. Consequently A. Finkl & Sons Co. selected Vacuum Arc Degassing (VAD) which introduces no foreign elements and permits simultaneously attaining the desired sulfur level and teeming temperature.

A Parametric Study of Fatigue Crack Growth Behavior in Adhesively Bonded Metallic Structures1

K. Arin.3 The author presents a valuable piece of work regarding the bonded structures. The amount of work, both analytical and experimental, is rather extensive in this area (see authors' references as well as the references therein). However, this paper serves a very useful purpose by comparing mathematical, finite element as well as experimental results obtained by him and other authors. The conclusion that analytical techniques can reliably predict (as experimental results indicate) the crack growth behavior in bonded structures is a significant one. It justifies the use of theoretical approach since this is also straightforward and much less expensive than the other alternatives. Moreover, it is well known that the added benefit of this approach is that it provides information on the fundamental characteristics of a given problem (i.e. composites with interface flaws) which cannot be obtained by other means. Another important conclusion to be noted is that the effect of bending should be taken into account to get close agreement with the experiments.

Similar investigations can be extended to the cases involving orthotropic plates [1].

Additional Reference

1 Arin, K., “Several Intact or Broken Stringers Attached to an Orthotropic Sheet with a Crack,” to appear in Engineering Fracture Mechanics.

Author’s Closure

I would like to thank Dr. Arin for his valuable discussions and comments. Our experience has shown that the use of mathematical methods is indeed less expensive than the finite element method. Hence mathematical methods are well suited for parametric studies.

The finite element method discussed in the paper is being currently used to analyze composite to metal bonded structures. The analytical results will be compared with experimental results. The results will be published in a forthcoming paper.

2General Electric Company, Schenectady, N.Y.
3Number [1] in brackets designates an Additional Reference at end of Discussion.

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