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EVALUATING THE BONDED JOINTS CHARACTERISTICS USING MODAL MODEL FUNCTION.

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ABSTRACT

In the present research, the behaviour of a metallic joint bonded with an epoxy film adhesive is investigated. In fact, until now there is no certain technique available to detect and evaluate the interfacial characteristics of bonded joint.

In this work, an impact vibration technique is used for measurement of global bonding joint characteristics utilizing model analysis.

The vibration signal is recorded using dual channel analyzer. Damping, frequency and mode shapes are obtained directly from the experimental results. Complex dynamic modulus and velocity of the sound are calculated using the obtained results from the modal test. The dynamic stiffness is determined using the frequency response function graphs.

The results showed that; the frequency response measurements can be successfully used to determine certain dynamic properties specially in bonding, 1) The frequency response function describes the dynamic properties of structures with bonded joints using a small set of parameters extracted from the measured data, and 2) There is a frequency dependance on the elastic modulus, damping, complex elastic modulus and wave velocity of the bonding joint which depends on the adhesive ratios and joint dimensions.

NOMENCLATURE

A : Vibration acceleration, arbitary units,
d : Joint diameter, mt,
E : Elastic modulus, N/m^2,
E' : Elastic modulus, real part,

E'' : Elastic modulus, imaginary part,
F : Exciting force, arbitary units,
f_n : Resonant frequency, of n th mode, Hz,
A/F: Vibration accelerance, dB,
K : End condition depends on fixing method and mode number,
L : Joint length, m,
n : Mode number,
t : Adhesive thickness, μm,
V : Wave velocity (sound velocity) m/sec,
ρ : Mass density, kg/cm^3,
ζ : Material damping factor, (%),
Δf : -3dB, bandwidth,

1- INTRODUCTION

In the present work, a modified technique is utilized for investigating the dynamic behaviour of bonded joint under impact vibration force.

The behaviour of adhesively-bonded joints depend on various of factors, such as a cohesive strength of the adhesive and/or the interfacial bonding strength between the adhesives and the adherends/1/. The physical forces at the interface depend mainly on the surface structure, its morphology, the composition of the adherends and their affinity to the adhesive /2/. Generally, a failure of an adhesively-bonded joint is defined as a cohesive of the adhesive layer /2/. Failure of adhesive bonded joint could be also attributed to inadequate understanding of the adhesion failure mechanics /3/. There are many investigations which concerned with the failure modes /3,4 and 5/. Most of them considered the behaviour under static conditions.

The terms which has been neglected in most of the previous work, such as the behaviour of bonded joint under impact vibration force, type of fixation and adhesive thicknesses will be considered in the present work.

2- EXPERIMENTAL WORK

1.2- Types of Specimens

The joint consists of two adherends with interface adhesive layer as shown in Fig.(1). It is manufactured from mild steel. The mechanical properties and chemical composition of mild steel are shown in Tables (1) and (2) respectively.

Mechanical	σ_u	σ_y	E	B.H.	% Elongation
Properties	260 M Pa	130 M Pa	207 G.Pa	≃106	45

Table (1) Mechanical properties of specimen material.

Chemical	Fe	Si	Mn	Ni	Cr	Mo	S	P	C	Cu	AL
Composition	bal	0.117	0.85	0.1	0.12	0.004	0.046	0.036	0.267	0.35	0.004

Table (2) Chemical composition of specimen material.

2.2- Type of adhesive used

The type of adhesive is "superbonder 415 table 3". This adhesive is used for fast bonding of metals and porous surface. It has high impact strength, excellent solvent resistance, cures completely and leaves no residue on surface.

Specification at 20 °C	Chemical name	Colour	Viscosity	Typical Handling Strength	Typical Ultimate Strenght	Gap filling	Temp. range	Minimum shelf life
	Anearale	Amber	10 CPS	1 min	24 hrs 30 N/mm^2	0.25 mm	-55: 120°C	0:5°C 1 year

Table (3)

3- Experimental Procedure

The bonded surface for each specimen is cleaned and removed foreign matter by using a cloth dipped with acetone solution. Then, the measurement of the surface roughness is performed by using Talysurf 5- M60 instrument.

The two adherends should be selected according to the surface roughness values which appropriate for each adherend. The two parts of bonded specimens are made from the same metal or a combination of two metals. Preparation of the surfaces to bonded and the mixing of adhesive are made according to recommendations of manufacture adhesive in each case /9/.

The measurement technique which used in this research is shown in Fig.(2a) and described as follows; it is based on impact excitation testing technique, which is chosen since it give quick results, the impulse contains energy at all frequencies and will excite all modes simultaneously.

The vibration signal is picked up using very light piezo electric accelerometer. The input and output signals (force & vibration) are connected with dual channel signal analyzer which was equipped with personal computer as shown in Fig.(2a).

On the basis of the experimental results of the eigen-frequencies, Fig.(2b), the flexability of damping criteria of both continuous and bonded joints are computed and plotted in Figs.(7 to 10).

4- RESULTS AND DISCUSSION

The elastic Young's Modulus, damping, complex elastic modulus, dynamic stiffness and wave velocity are determined experimentally using modal model method, by performing modal test of the joints.

Elastic Young's Modulus : The modulus of elasticity "E" in the absence of damping can be found from the resonant frequency, mechanical dimensions of the joint, density of material and boundary conditions "End condition" from the following relation (8);

$$E' = 48\,\pi^2\,\rho\left(\frac{L^2}{d}\cdot\frac{f_n}{k_n{}^2}\right)^2 \qquad N/m^2 \qquad (1)$$

Fig.(3) presents the frequency dependance on elastic modulus for fixed-free case with two values of adhesive thickness (200 and 300 μm). This figure indicates that, when the frequency increase the elastic modulus decreases in the range of 250 to 950 Hz. This may be due to the mutual effects of the mechanical properties of the adhesive material and mild steel in the interface region. Fig.(3) indicates that, the frequencies decrease in the region of the adjacent of the bonded joints. The region is mainly affected by the adhesive thicknesses. The elastic modulus values is large comparing with the results of continuous joint. The increase of the adhesive thickness increases the elastic modulus of the joint. In the case of (300 μm) thickness, the deviation between E values comparing with continuous joint is very clear, it is about 10%. Fig.(4) presents the frequency dependance on elastic modulus for fixed-fixed case of the same metal under the same conditions. This figure indicates that, the values of elastic modulus are less than the values which shown in Fig.(3), and the high modes are very sensitive to adhesive thickness. The results of elastic modulus when using (t=300 μm) is large comparing with continuous joint and (t=200 μm). Now, the adhesive thickness and type of clamping play an effective role in the behaviour of the joint for the same dimensions.

Fig.(5 and 6) presents the frequency dependance on elastic modulus under the same conditions of Fig.(3 and 4). In this case the diameter of the joint is changing from 30 mm to 40 mm. From these figures, the amplitudes are large than the previous case specially for Fix-Fix condition. This may be due to the increasing of joint diameter and with the increased in adhesive thicknesses. From the same figures the effect of adhesive thickness is very clear as shown in the previous figures.

Damping : Figs.(7 to 10) presents the frequency dependence on the damping ratios under the same conditions of the previous figures. This is expected, since as the frequency increases the damping ratio decreases. From the same figures, when the adhesive thickness values increases comparing with the continuous joint, using diameter of joint equal 40 mm, the damping ratio increases as compared with fixed-fixed case which represented in Figs.(9 and 10). Increasing damping ratio depends on many factors such as, the adhesive thickness, type of fixation and joint diameter.

Complex Elastic Parameters : Due to the demands of high speed operation and the use of light structures in modern machinery static measurements of stress/strain properties are not sufficient. The static determination of the elastic modulus does not takes into account the frequency or internal friction (damping). It is clear from the results of the elastic modulus and damping, there is a frequency dependance of these parameters. In the case of adhesive joint the internal damping is to be considered and the modulus of elasticity becomes a complex value. The complex value is the vectorial sum of the elastic and damping moduli which calculated as follows /7/.

$$E = E' + i\,E''$$

and ; $E'' = 2\,\zeta\,E'$

while the damping factor is;

$$\zeta = \frac{L}{2} \cdot \frac{\Delta f}{f_n}$$

From the modal test (frequency response), the complex elastic modulus can be determined. It is obvious that the results depend mainly on the constituent ratios of the adhesive and joint conditions.

Figs.(11-14) present the frequency dependance of accelerance (A/F) for the various boundary conditions. This relation (A/F) can be taken as a measure of the dynamic stiffness. The using of accelerance of vibration as a preferred parameter because it covers a wide range of frequency and gives flatest spectrum. Since the displacement, velocity and acceleration of vibration signals one directly related, thus, use vibration accelerance (A/F) as a measure of inverse of the dynamic stiffness.

From Figs.(11-14), the dynamic stiffness which is proportional with (A/F) decreases with an increases in frequency, adhesive thickness, diameter of specimen, and type of fixation. These results may be due to the greater deflections produced from the vibrating force comparing with the elastic conditions and due to the behaviour of adhesive material under effects of dynamic force. From the previous figures, it is clear that, the Fix-Fix case gives higher results comparing with the Fix-Free case because the first case increasing the stiffness of the joint. The increase of (A/F) with the increase of frequency is either due to the decrease of damping with frequency or as a result of the decrease of dynamic stiffness.

The equation of the compressional vibrations has the same form as so-called wave equation which governs various types of wave phenomenon in theoretical physics. Compressional vibrations are referred to as mechanical waves with a wave velocity (V)

$$V = \sqrt{E/\rho}$$

This parameter is very important because; the actual vibrations measured on a complicated structure may be widely different from point to point, and from space direction to another. The wave solution is most useful for simple systems and for excitation of a very short duration, while for practical engineering analysis, we will find vibration solution to be most useful.

Figs.(15-18) present the frequency dependance on wave velocity. The wave velocity is directly related to the elastic modulus and inversely related to the density roots. From these figures it is clear that, the decreases of sound velocity with the increase of the frequency. The drop in elastic modulus for a certain frequency makes the wave velocity increases with the decrease of adhesive thickness because the adhesive thickness transmit the vibration signals or waves more difficult than the metal.

5- CONCLUSIONS

The frequency response measurements can be used successfully to obtain certain dynamic property specially in bonding. From the previous results it can be concluded that;

1- The frequency response function describes the dynamic properties of structures using a small set of parameters extracted from the measured data.

2- There is a frequency dependance on the damping, complex elastic modulus and wave velocity.

3- The bonding joint behaviour depends on the adhesive ratios and joint dimensions.

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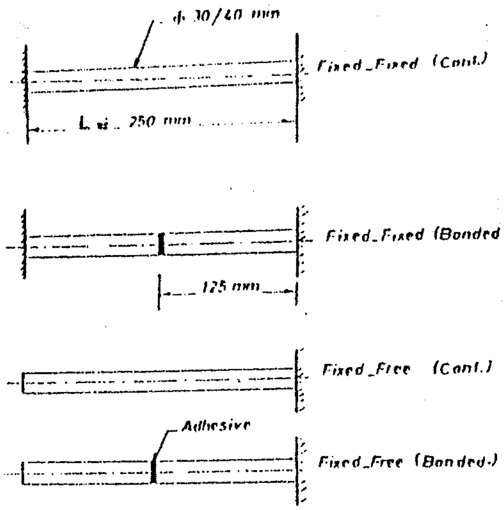

Fig.(1) Specimens Shape and Type of Fixation.

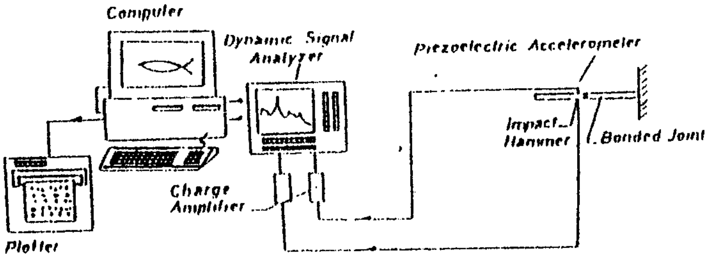

Fig.(2a)Block Diagram of the Experimental Set.

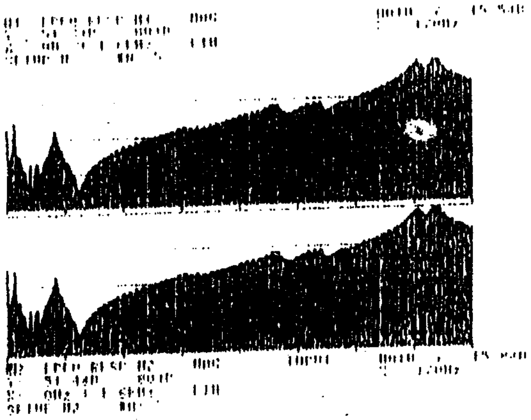

Fig.(2b) Frequency response of a test sample.

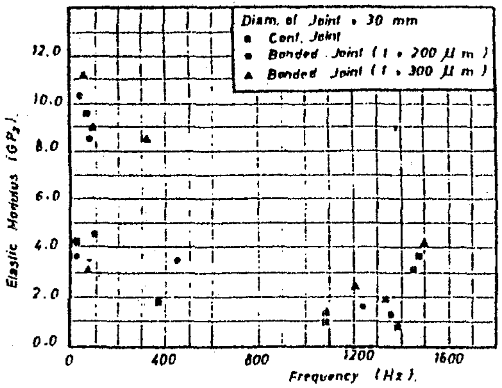

Fig. (3) Frequency Dependance on Elastic Modulus For (Fixed_Free Clamping).

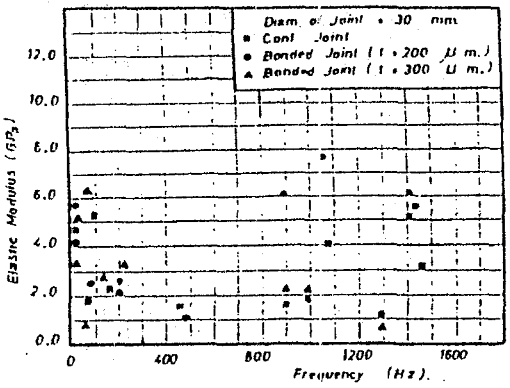

Fig. (4). Frequency Dependance on Elastic Modulus For (Fix_Fix Clamping).

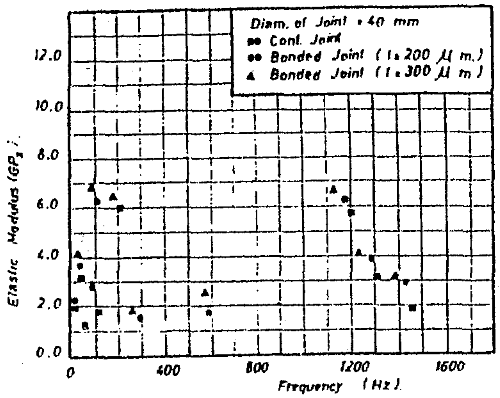

Fig. (5). Frequency Dependance on Elastic Modulus For (Fixed_Free Clamping).

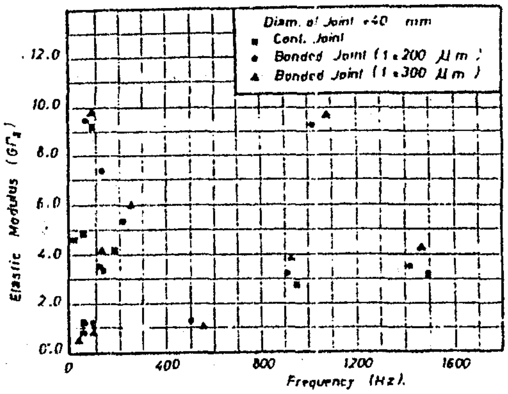

Fig. (6) Frequency Dependance on Elastic Modulus For (Fixed_Fixed Clamping)

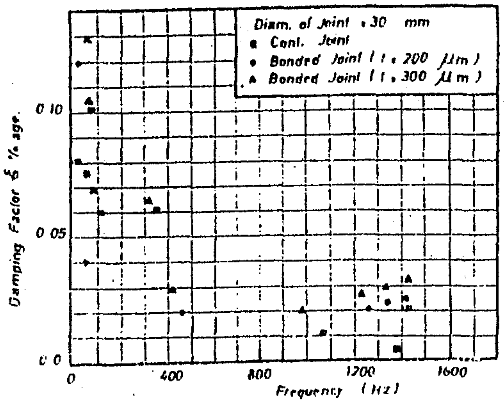

Fig. (7). Frequency Dependance on Damping Factor (Fixed_Free Clamping).

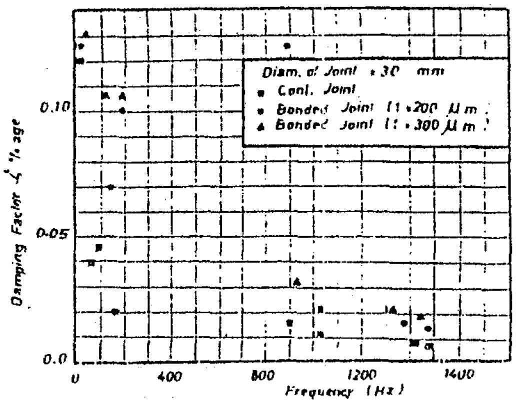

Fig. (8). Frequency Dependance on Damping Factor (Fixed_Fixed Clamping).

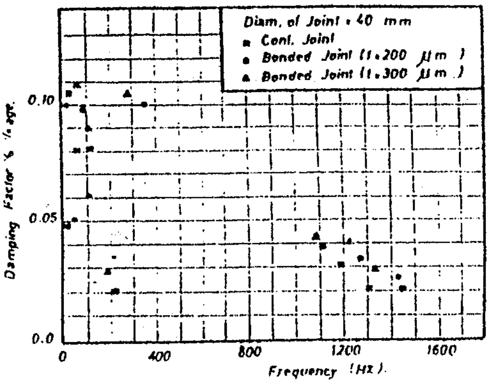

Fig.(9) Frequency Dependance on Damping Factor (Fixed_Free Clamping).

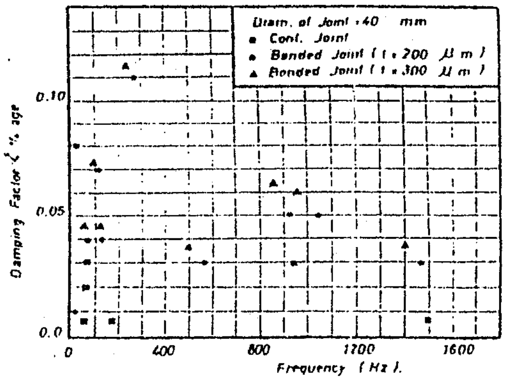

Fig.(10). Frequency Dependance on Damping Factor (Fixed_Fixed Clamping).

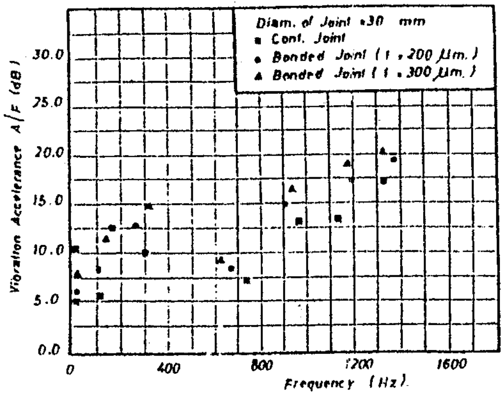

Fig.(11). Frequency Dependance on Vibration Accelerance (Fixed_Free Clamping).

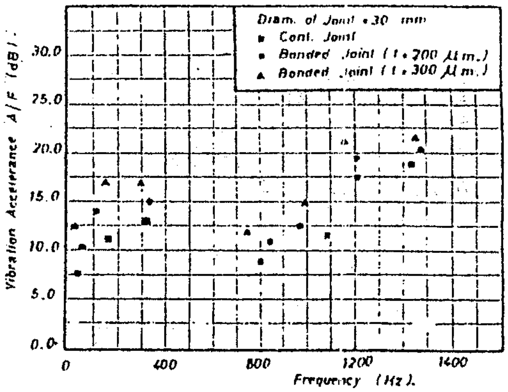

Fig.(12) Frequency Dependance on Vibration Accelerance (Fixed_Fixed Clamping).

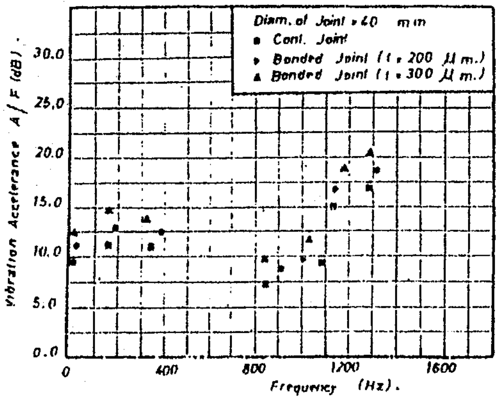

Fig.(13) Frequency Dependance on Vibration Accelerance (Fixed_Free Clamping).

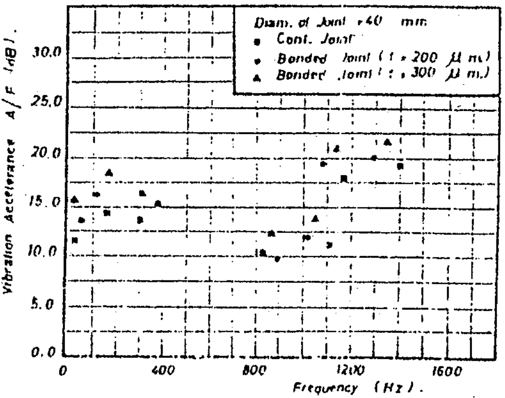

Fig.(14). Frequency Dependance on Vibration Accelerance (Fixed_Free Clamping).

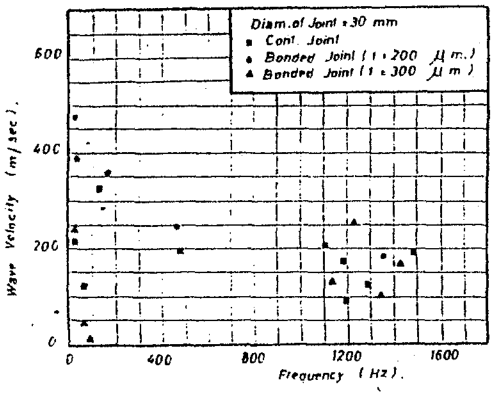

Fig.(15).Frequency Dependance on Wave Velocity (Fixed _ Fixed Clamping).

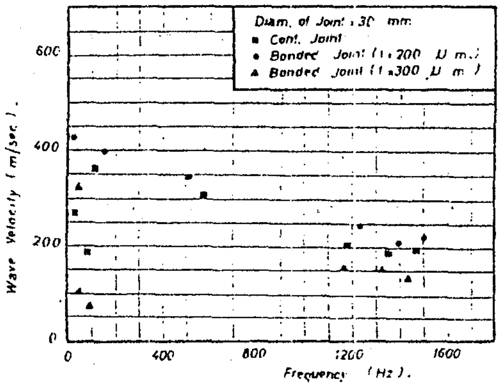

Fig.(16).Frequency Dependance on Wave Velocity (Fixed _ Free Clamping).

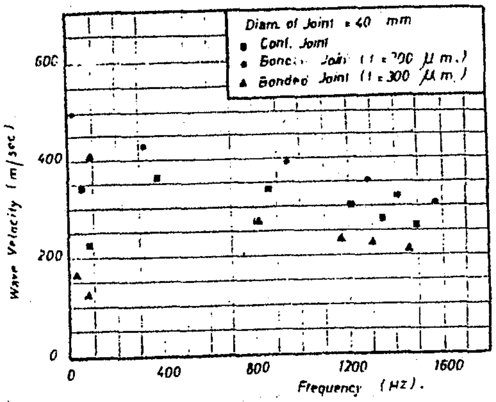

Fig.(17) Frequency Dependance on Wave Velocity (Fixed _ Free Clamping).

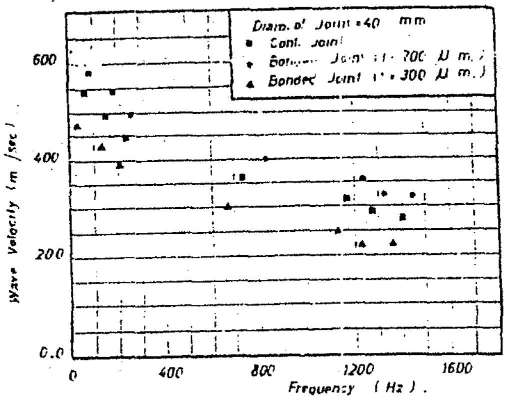

Fig.(18). Frequency Dependance on Wave Velocity (Fixed_Fixed Clamping).

Evaluating The Bonded Joint Characteristics Using Modal model Function.

عنوان البحث باللغة العربية:

تقييم أداء وصلة اللصق باستخدام نموذج الداله الشكلى (Modal Model Function)

د/ احمد محمود على عيسى

(هندسة الانتاج و التصميم الميكانيكى)

فى هذا البحث تمت دراسة سلوك وصلة اللصق المعدنية باستخدام (Modal Model Function) لأنه فى الحقيقة حتى الأن لم يقدم تكنيك معين يعمل على كشف وتقييم أداء الوصلة الملصوقة ، ولقد تم فى هذا البحث إستخدام تقنية الاهتزازه الصدمية لاجراء عمليات القياس والتقييم لأداء الوصلة مستفيدين من النموذج التحليلى.

لقد تم تسجيل إشارة الاهتزازه باستخدام Dual Channel Analyzer واستنتجت مباشرة قيم كل من: الاخماد والتردد وشكل Mode من النتائج العملية – أما معامل المرونة الديناميكى المركب وسرعة الصوت فقد تم حسابها باستخدام النتائج السابقة. وتم حساب Dynamic Stiffness باستخدام نماذج الرسم ل. Frequency Response.

من النتائج الهامة لهذا البحث أنه يمكن إستخدام قياسات Frequency Response بنجاح فى حساب الخصائص الديناميكية لوصلات اللصق – ويمكن باستخدام هذا النموذج وعدد قليل من عناصر الوصلة الملصوقة مستخلصة من القيم المقاسة – معرفة الخصائص الديناميكية لوصلات اللصق. وأيضا أظهرت النتائج أن هناك تاثير ل. Frequency على معاير المرونة والاخماد ومعاير المرونة المركب وسرعة الصوت فى الوصلة الملصوقة والتى تعتمد أساسا على نسب المادة اللاصقة وأبعاد الوصلة.

مساهمة البحث فى الصناعة:

إستخدام هذا النموذج فى إختبار وصلات اللصق دينامبكيا يؤدى إلى التخلى عن إجراء الاختبارات المتلفة للوصلات فى الصناعة لأنه يكشف الأداء الديناميكى لمعظم عناصر الوصلة.