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Araştırma Makalesi / Research Paper

Algorithm Developed for Preventing Time Loss Calculating RMS of Vibration Signals

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ABSTRACT

In this work, an algorithm is developed to prevent time losses that occur during the calculation of Root Mean Square (RMS) of the vibration signals. Vibration signals are obtained during cutting of super alloy material Inconel 718 on a CNC lathe machine with a cutting speed of 50 meters per minute, 0.15 mm progress per revolution and 2.5 mm cutting depth. The data is loaded to the computer via the vibration sensor (353B31 from PCB Piezotronic) and the digital-analog converter card (DAQ 6062E) and then mathematical expressions are created in Matlab environment. RMS is one of the most important evaluation parameters in the evaluation of this data. Running the classical algorithm, it is observed that there was excessive time loss in the RMS calculation of total 120 million data about 60 tests, each test lasted about eight hours. So a new algorithm has been developed that can do operations much faster. The results of the new algorithm are compared with the results of the classic algorithm and it is determined that the new algorithm produces 100% correct results. 99% of the time loss is avoided with this new algorithm.

Keywords: Vibration Signal, RMS, Cutting Tool

Titreşim Sinyallerinin RMS İle Hesaplanmasında Zaman Kaybının Önlenmesine Yönelik Geliştirilen Bir Algoritma

ÖZ

Bu çalışmada; titreşim sinyallerinin kare ortalamalarının karekökü (RMS) hesaplanması sırasında meydana gelen zaman kayıplarının önüne geçilmesine yönelik bir algoritma geliştirilmiştir. Titreşim sinyal verisi; Inconel 718 adlı süper alaşım malzemenin, CNC Torna tezgâhında; 50 metre/dak kesme hızı, 0,15 mm/devir ilerleme hızı, 2,5 mm kesme derinliğindeki kesimi sırasında elde edilmiştir. Veriler titreşim sensörü (PCB Piezotronic'e ait 353B31) ve dijital-analog çevirici(DAQ 6062E) kartı ile bilgisayara alınmış ve Matlab ortamında matematiksel ifadeler oluşturulmuştur. RMS ise bu verilerin değerlendirilmesinde önemli değerlendirme parametrelerden bir tanesidir. Klasik algoritmada, yaklaşık 60 testlik toplam 120 milyon verinin işlendiği RMS hesaplamasında aşırı zaman kaybı olduğu gözlemlenmiş; her bir test yaklaşık sekiz saat sürmüştür. Bundan dolayı işlemleri çok daha hızlı yapabilen yeni bir algoritma geliştirilmiştir. Yeni algoritma ile klasik algoritmanın sonuçları karşılaştırılmış ve yeni algoritmanın %100 doğru sonuçlar ürettiği tespit edilmiştir. Yeni algoritma ile zaman kaybının %99 oranında önüne geçilmiştir.

Anahtar Kelimeler: Titreşim Sinyali, RMS, Kesici Takım

INTRODUCTION

Root Mean Square is also named as Effective Value. It is a method used to calculate variables such as force, voltage and current (Michale and Heydt, 2003; Kuo and Lee, 2001). A peak and RMS graph of a sinusoidal signal is shown in Figure 1. It becomes a problem to measure the voltage applied to the load and transfer it to the evaluation unit at distortions in the shape of the sinus signal and in the phase-dependent control studies of the sinus signal. Especially, stability of the output voltage is an expected feature in phase-dependent power control circuits. Obtaining a stable output voltage in such systems is only possible with the fastest and most accurate measurement results (Gençer, 2009).

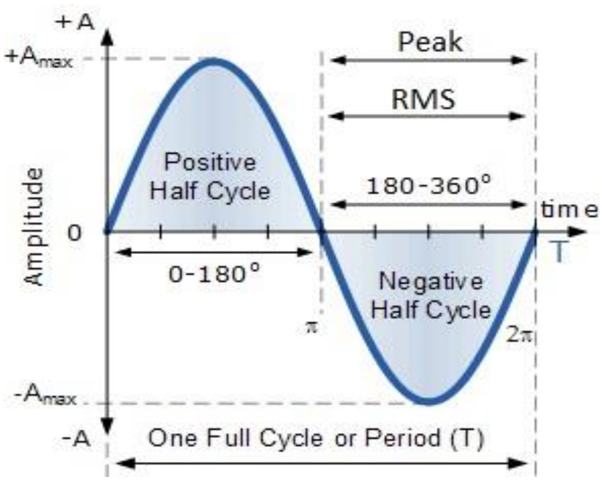

Figure 1. Sinus Signal

The formulas in the RMS calculation vary to the wave shape formation such as full wave or half wave. Each RMS calculation is based on a different algorithm and provides a true and accurate calculation. Many methods are used to measure the effective values of electrical signals. These methods can be summarized in two titles as comparison and calculation methods (Wey and Huang, 2000).

An effective value measurement system that takes samples at regular intervals is calculated as in equation (1.1) where "n" is the number of samples and "X" is the effective value of instant sinus signals at sampling time (Vujicic et al., 1999).

The following steps are taken when calculating the RMS value of a mark as discrete (digital);

- Amplitude values are taken at a specific sampling time over a period of the signal
- Calculates addition of squares of each values
- Addition is divided to total number of samples
- Square root of this result is the RMS.

$$\mathrm{x_{rms}} = \sqrt{\frac{1}{\mathrm{n}}(X_1^2 + X_2^2 + X_3^2 + X_4^2 \dots + X_n^2)} \qquad (1)$$

The higher measurement accuracy depends to higher sampling frequency while RMS is being calculated.

Measuring the effective value (Ueff) of the voltage (u(t)) in alternating and arbitrarily shaped electrical signals has a great importance in automation and control technologies when the RMS value of a mark is calculating continuously (analog). Xrms is calculated as in Equation 1.2 in effective value measurement systems (Germer, 2000).

$$\mathrm{x_{rms}} = \sqrt{\frac{1}{\mathrm{T}}\int_0^{\mathrm{T}} \mathrm{x}^2\,(\mathrm{t})\mathrm{dt}} \qquad (2)$$

Equation 1.2 is used when measuring continuous signals. The calculation method is discrete time signal processing. A discrete time signal can be referred to as a sampling frequency (fs). This sampling frequency must be at least double of the input frequency (fi) according to the Nyquist theorem (Equation 1.3). For accurate measurement results, the sampling frequency should be kept as high as possible (Germer, 2001).

$$\mathrm{fs} \geq 2\mathrm{f} \qquad (3)$$

MATERIAL AND METHODS

In this study, Equation 1.1 is used to calculate the digital offset at each point. Vibration is a sinus data with amplitude and angle. So it should be considered as a vector and separated into components by reducing projections to a Cartesian coordinate system. These vector quantities should be considered as amplitude, floating point, speed and acceleration (Mitsubishi, 2005). In the case of difficult calculations, data size reduction methods help to avoid the occurrence of time and computation errors in some cases for classification (Hall, 2000; Guyon and Elisseeff, 2003; Yu and Liu, 2004). In such cases, the process is performed in a shorter time by selecting some attributes from the data and only making calculations on them (Genç et al., 2007).

Dataset used in this study is obtained during cutting of super alloy material Inconel 718 on a CNC lathe machine with a cutting speed of 50 meters per minute, 0.15 mm progress per revolution and 2.5 mm cutting depth. Vibration is the oscillation movements of a system in different directions from the stationary equilibrium are called vibrations. Period is the movement of the released oscillation back to its starting point in the process T as in shown in Figure 1. Especially, too much vibration occurs when the mechanical tools are working. The vibration is observed in both directions while cutting a hard material. In such cases, vibration negatively affects the time and quality of the work. It will have positive effects in terms of time and quality by calculating the amplitude at which the vibration occurs and trying to minimize it. The observed data was digitized with Cut-Pro software and then compiled and evaluated in Matlab during this vibration detection.

PCB Piezotronic's 353B31 sensor is used as the vibration sensor as it is shown in Figure 2. The purpose of using this model is the suitability of its vibration sensitivity for this work. In addition to the vibration sensor, a data acquisition card and signal regulator are also used.

Figure 2. PCB 353B31 vibration sensor

The data gained from the vibration sensor is transferred after the signal collector to the computer via the data collection card DAQ 6062E which is shown in Figure 3.

Figure 3. Data collection card

Data collection card DAQ 6062E uses 12 bit analog signal for 1.25 Mega Signals per second data input, has 2 analog outputs and 8 digital input / output channels, 2 x 24 bit counter and has ability to view more than 70 signals at a time.

The digital calculation of the amplitude value of the vibration will be far from scientific approach by means of finding an average. It is because of double-sided oscillations which results in values close to zero in amplitude values. In such cases, using RMS method will be more accurate (Güngör, 2011).

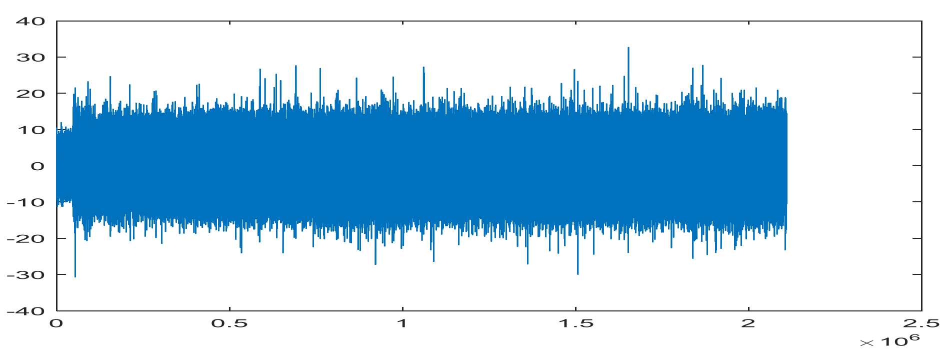

Figure 4. Vibration data in the time-amplitude plane

Figure 4 shows approximately 120 million pulses of vibration which were obtained in one parameter during one hour of cutting process. It takes a lot of time to calculate the RMS of such a high-volume data.

When 120 millions of data are calculated in RMS, the cursor reaches the desired index each time, computes the square of the data contained in this index and assigns the result to a variable. Then the cursor returns again to the square value of the next indexed data. This process is shown in Figure 5. 120 million data were obtained as a result of about 60 tests. It can be said that about 2 million data were obtained per test.

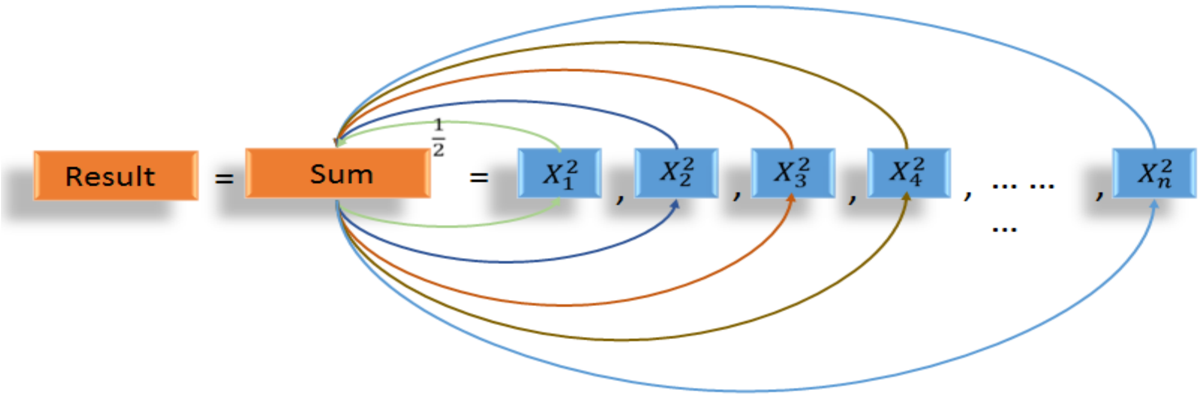

Figure 5. Flowchart for classical algorithm

The calculation of the RMS value for a single test takes about 10 hours on a computer with an Intel Core i5 2.0 Ghz processor and 4 GB RAM. The main reason for this long time period can be described as in Figure 5. The algorithm used for this operation is as follows;

```
{
        k ← length(data)
        for (i=1 to k)
        {
        x(i) ← sqr(data(i,1))
        }
        grandtotal ← sum(x)
        y ← grandtotal /i
        RMS ← sqrt(y)
}
```

This algorithm is expressed on Matlab as follows;

```
clear all // Clear
load test.mat // Load mat file
k=length(data); // Assign data length of each test to a variable k
for i = 1:k; // Start loop as k times
    x(i)=data(i,1)^2; // Add the square of data in each index to that index data
end // End loop
total=sum(x);     // Add squares
y=total/i;     // Divide total of squares to number of samples
rms=sqrt(y); // Take the square root to calculate RMS
save test.mat // Save data
```

As it is seen, algorithm reaches each indise one by one, calculates the squares and transfers to the total variable. This process is consists of 3 jobs which are find index, calculate square, transter to total variable fort he first index. But when it reaches to index number 100000, number of jobs increase to 100002 becasuse, algorithm makes comparisons one by one to each index until reaching the expected index. This leads to a non-linear increased time loss. In order to avoid this problem, an algorithm as shown in Figure 6 which does not increase non-linearly.

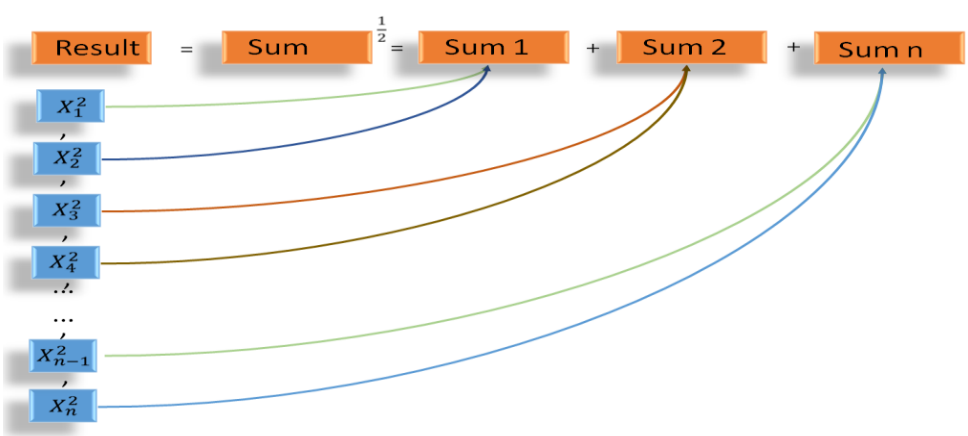

Figure 6. Flowchart of developed algorithm

Developed algorithm divides the data into the appropriate data processing intervals and then performs RMS calculation. Thus avoids time spent for index controls. The new algorithm developed is as follows;

```
{
        l ← length(data)/10000
        for (i=1 to l)
        {
          newdata(1:10000,i)          ←          data((((i-
        1)*10000)+1):i*10000)
        }
        k ← length(newdata)
        for (j=1 to l)
        {
          for(i=1 to k)
          {
          x(i,j)←sqr(newdata(i,j))

          }
        }
        grandtotal ← sum(x)
        y ← total/(k*l)
        RMS ← sqrt(y)

}
```

Matlab code of developed algorithm is as follow;

```
clear all // Clear
load test.mat // Load mat file
 l=length(data)/10000; // Divide data lentgh of each test
to 10000 and assign the result to variable l
for i=1:l; // Start loop as l times
                newdata(1:10000,i)=data((((i-
1)*10000)+1):i*10000); // Place the data which is in a
single row into a new series each consisting of 10000
data
End // End loop
k=length(newdata); // Assign the length of new data to
variable k
for j=1:l; // Start loop as l times
                for i = 1:k; // Start loop as k times
                x(i,j)= newdata(i,j)^2; // Calculte the square
of data in each index
    end // End loop
End // End loop
total=sum(x); // Assign sum of squares to variable top-
lam
y=total/(k*l); // Divide toplam to number of data
(rms=sqrt(y); // Calculate RMS by taking square root
save test.mat // Save data
```

CONCLUSION

In a system with 2 million records, the cursor can reach required index faster by dividing the data into new sequences each consisting of 10000 samples. On this count, blank index controls have been avoided. So the process lasted for about 10 hours with the classical algorithm is lasted only in 3 minutes with this new algorithm. Furthermore, initial 10 tests was applied with classic algorithm and the developed algorithm and it was observed that the results of the tests produces same figures.

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